RESEARCH AND COMPETITIVENESS IN THE CONSTRUCTION INDUSTRY

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

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*Ranking Republican Member.
**Resigned February 19, 1987 (H. Res. 89).
***Elected March 30, 1987 (H. Res. 133).
****Ex-Officio, voting member.

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Dr. Richard N. Wright, Director, Center for Building Technology, National Bureau of Standards, accompanied by Dr. John W. Lyons, Director, National Engineering Laboratory, National Bureau of Standards; Dr. David Haviland, chairman, National Academy of Sciences Committee on Construction Productivity, Rensselaer Polytechnic Institute; Dr. Fred Moavenzadeh, director, Center for Construction Research and Education, MIT; and Dr. John Fisher, Fritz Laboratory, Lehigh University 8

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RESEARCH AND COMPETITIVENESS IN THE CONSTRUCTION INDUSTRY

THURSDAY, JUNE 4, 1987

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:42 a.m., in room 2318, Rayburn House Office Building, the Honorable Doug Walgren (chairman of the subcommittee) presiding.

Staff Present: Ron Williams, Raphael Panitz and David Goldston.

Mr. WALGREN. Well, I apologize for the delay. This morning we're here to discuss the research needs and the competitive problems of the U.S. construction industry.

We have two panels of witnesses that will give us testimony on that issue, the first made up of University and Government witnesses who will provide an overview of construction industry problems and the currently discussed solutions, and the second panel will talk about the current state of the home building industry, and the heavy construction industry.

The health of the building industry is of vital importance to the nation's economy. It probably should go without saying, but in 1986 alone the U.S. construction industry had sales of $375 billion at home and abroad. This included residential and non-residential buildings, industrial and utility plants, transportation facilities, water and sewer construction projects and others.

The economic well being of the construction industry directly affects the American economy. They are generally the index as we watch when we are trying to guess whether things are getting better or getting worse. When that industry declines, it adversely affects a wide range of workers in a host of different capacities in our economy, boilermakers, carpenters, electricians, painters as well as those who produce the materials and produce the mechanical equipment and all the necessary components thereof.

Recently released statistics point to a 2 decade long downward trend in the productivity of the U.S. construction industry. Construction share of the GNP has fallen, and the volume of U.S. construction business abroad has sharply declined. The number of foreign companies acquiring U.S. construction firms has been on the increase as has the number of foreign firms acquiring direct construction contracts in the United States.

Research and development also present problems. The construction industry in the U.S. is divided and broken up into many small

firms where R&D or modernization is really not a part of their world. The U.S. construction industry invests far less in research as a percentage of sales than almost any other industry that we have.

As with so many other industries, technological advancement and innovation do hold the key to tremendous increases in productivity and therefore certainly the key to the competitiveness of any entity that can make that kind of advance. This has not been lost on foreign competitors in this area.

The Japanese, the Swedish interests and the like are making major strides to increase their market share and I think it's clear that as we think of competitiveness for the economy as a whole, if this industry is impacted on a wholesale level as have some other industries, and I think in particular the steel industry where there has been over the last 8 years or so almost a wholesale collapse of the industry. If this industry were to collapse at the same rate that the steel industry has collapsed, this economy would never be able to maintain any degree of economic activity let alone prosperity.

So we appreciate the witnesses coming to talk with us about this subject. It is an important one and we look forward to the testimony.

I want to ask and note that we will have unanimous consent that cameras and press coverage be allowed at this hearing in whatever fashion may serve the purposes of those involved

I'd like to call the first panel, but particularly ask Dr. Lyons who many of you who follow this area know is the Director of the National Engineering Lab to introduce Dr. Richard Wright who is the Director of the Center for Building Technology at the National Bureau of Standards. Dr. Haviland, the Chairman of the National Academy of Sciences Committee on Construction Productivity, Dr. Wright, from the Bureau, Dr. Moavenzadeh, who is the Director for Center for Construction Research and Education at M.I.T. and Dr. John Fisher of the Fritz Laboratory at Lehigh University, if you folks would come forward we'd appreciate your joining us.

With that let me recognize Dr. Lyons. Welcome.

[The prepared opening statements of Hon. Doug Walgren and Hon. Sherwood Boehlert follow:]

OPENING STATEMENT OF THE HONORABLE DOUG WALGREN ON RESEARCH AND COMPETITIVENESS IN THE CONSTRUCTION INDUSTRY

June 4, 1987

This morning we are here to discuss the research needs, and competitiveness problems of the U.S. construction industry. Two panels of witnesses will give us testimony on this issue. The first panel, made up of University and Government witnesses, will provide an overview of construction industry problems and their solutions. The second panel will discuss the current state of the home building industry and the heavy construction industry.

The health of the building industry is of vital importance to the nation's economy. In 1986 alone, the U.S. construction industry had sales of $375 billion at home and abroad. This included residential and non-residential buildings, industrial and utility plants, transportation facilities, water and sewer construction projects, and elsewhere. The economic well-being of the construction industry impacts positively on the American economy, and when that industry declines, it adversely affects a wide variety of workers including boilermakers, carpenters, electricians, masons, and painters as well as producers of construction materials, mechanical equipment, white goods, and other building contents.

Recently released statistics point to a 2-decade long, downward trend in the productivity of the U.S. construction industry. Construction's share of the GNP has fallen, the volume of U.S. construction business abroad has sharply declined, and the number of foreign companies acquiring U.S. construction firms or contracts has increased.

Research and development (R&D) also presents problems. The construction industry in the U.S. is fragmented with many small firms where R&D or even modernization is often not a problem. The U.S. construction industry community invests far less in R&D as a percentage of sales than most other U.S. industries.

As with so many other industries, technological advancement and innovation may hold the key to increased productivity and competitiveness, and this is not lost on the Japanese, the Swedes and others making major strides to increase their market share.

The time for complacency and business as usual is past. The research decisions we make today, more than ever before, will affect the strength of the construction industry of the 1990's and beyond.

HON. SHERWOOD BOEHLERT (R-NY)
OPENING STATEMENT
HEARING ON COMPETITIVENESS OF THE CONSTRUCTION INDUSTRY
JUNE 4, 1987

MR. CHAIRMAN:

THIS MORNING'S HEARING COMES AT A PIVOTAL POINT IN THE HISTORY OF OUR NATION'S CONSTRUCTION INDUSTRY. AMERICAN CONSTRUCTION FIRMS AND THEIR SUPPLIERS ARE FACING INCREASING COMPETITION BOTH AT HOME AND ABROAD, WHILE NEW TECHNOLOGIES HOLD OUT THE HOPE OF MAKING BUILDINGS CHEAPER, SAFER AND MORE EFFICIENT.

MUCH IS AT STAKE. THE CONSTRUCTION INDUSTRY IS IN MANY WAYS THE KEYSTONE OF OUR ENTIRE ECONOMY. THE INDUSTRY ITSELF ACCOUNTS FOR ABOUT 8 PERCENT OF OUR GNP, AND THE QUALITY OF ITS PRODUCTS HELP DETERMINE THE PRODUCTIVITY AND THE PROFITABILITY OF THE REST OF AMERICAN BUSINESS. OUR VERY "QUALITY OF LIFE" IS DEPENDENT ON CONSTRUCTION FIRMS; AFTER ALL, THEY BUILD OUR HOMES, OUR SCHOOLS, OUR HIGHWAYS, OUR CHURCHES.

AND AS WE'VE SEEN TOO OFTEN RECENTLY, THE QUALITY OF CONSTRUCTION CAN BE A MATTER OF LIFE AND DEATH. THE COLLAPSE OF THE NEW YORK STATE THRUWAY BRIDGE IN MY CONGRESSIONAL

DISTRICT DEMONSTRATED VIVIDLY, AND TRAGICALLY, THAT WE CANNOT TAKE CONSTRUCTION QUALITY FOR GRANTED. A FEW YEARS AGO IT SEEMED LIKE EVERY POLITICIAN IN AMERICA WAS TOUTING THE NEED TO REBUILD OUR "INFRASTRUCTURE." THE HEADLINES HAVE DISAPPEARED, BUT THE PROBLEM HAS NOT.

THE CURE FOR OUR CONSTRUCTION PROBLEMS IS AS OBVIOUS AS IT IS IGNORED. THE CURE IS MORE RESEARCH.

NOW I DON'T MEAN TO SUGGEST THAT THE CURRENT INADEQUATE LEVEL OF RESEARCH IS THE SOLE REASON THE CONSTRUCTION INDUSTRY APPEARS TO BE IN THE DOLDRUMS. AND ALL THE RESEARCH IN THE WORLD WON'T MAKE A DIFFERENCE IF THE RESULTS ARE NOT APPLIED. BUT RESEARCH IS NEEDED TO AUTOMATE CONSTRUCTION, TO IMPROVE ENERGY EFFICIENCY, TO DEVELOP BETTER BRIDGE DESIGNS AND INSPECTION METHODS AND TO CUT CONSTRUCTION COSTS.

OTHER NATIONS UNDERSTAND THIS. THEY CONCENTRATE MORE ON RESEARCH THAN WE DO, AND THEY WATCH TO SEE IF WE'LL CATCH ON. SHORTLY AFTER I ORGANIZED A NATIONAL CONFERENCE ON CONSTRUCTION IN MY CONGRESSIONAL DISTRICT LAST JUNE, THE JAPANESE EMBASSY'S CONSTRUCTION ATTACHE CAME TO SEE ME, JUST TO CHAT ABOUT WHERE I SAW AMERICAN CONSTRUCTION HEADING. I DOUBT OUR EMBASSY IN JAPAN IS MONITORING THIS ISSUE WITH EQUAL DILIGENCE.

AT TODAY'S HEARING WE SHOULD BE ABLE TO GET A BETTER SENSE OF EXACTLY WHAT ENHANCED RESEARCH COULD DO FOR AMERICAN CONSTRUCTION. THE TESTIMONY WILL EXPAND UPON THE EXCELLENT NATIONAL ACADEMY OF SCIENCES STUDY OF THIS ISSUE, WHICH CONCLUDED THAT THE FEDERAL GOVERNMENT SHOULD BE SPENDING MORE ON CONSTRUCTION RESEARCH. I AGREE.

GOVERNMENT, INDUSTRY AND UNIVERSITIES ARE GOING TO HAVE TO WORK TOGETHER TO ENSURE THE LONG-TERM HEALTH OF THE CONSTRUCTION INDUSTRY, AND IN TURN, OF THE AMERICAN ECONOMY. THIS HEARING, ALONG WITH OUR COMMITTEE'S CONTINUING EFFORTS TO BUILD UP THE NATIONAL SCIENCE FOUNDATION AND THE NATIONAL BUREAU OF STANDARDS, SHOULD HELP SET US ON THE PROPER COURSE.

THANK YOU.

STATEMENTS OF DR. RICHARD N. WRIGHT, DIRECTOR, CENTER FOR BUILDING TECHNOLOGY, NATIONAL BUREAU OF STANDARDS ACCOMPANIED BY DR. JOHN W. LYONS, DIRECTOR, NATIONAL ENGINEERING LABORATORY, NATIONAL BUREAU OF STANDARDS; DR. DAVID HAVILAND, CHAIRMAN, NATIONAL ACADEMY OF SCIENCES COMMITTEE ON CONSTRUCTION PRODUCTIVITY, RENSSELAER POLYTECHNIC INSTITUTE; DR. FRED MOAVENZADEH, DIRECTOR, CENTER FOR CONSTRUCTION RESEARCH AND EDUCATION, M.I.T.; AND DR. JOHN FISHER, FRITZ LABORATORY, LEHIGH UNIVERSITY

Dr. LYONS. Thank you, Mr. Chairman. It's a pleasure once again to appear before you and the Subcommittee. I am here this morning to talk about—to address the topic of construction technology and particularly just to put in context the testimony that Dr. Wright, Director of our Center for Building Technology will offer in a moment.

About five years ago when our factory automation program was gaining momentum it occurred to some of us that there should be analogies between construction and factory production of goods in that they are both manufacturing processes with a finished product as the objective, and we could see that there were going to be considerable advantages to productivity of factory manufacturing by the application of the computer and a certain kind of analysis of the production process. So Dr. Wright and I set out about five years ago to test the hypothesis that there were strong analogies and that that kind of thinking applied to the construction and maintenance of buildings and other structures would have the same sort of payoff.

So we began a smallish program within the existing budget structure, and I may say that both Dr. Wright and I are just back from two weeks in Japan looking at this kind of technology. We're both stimulated and excited by the opportunities that we think it presents.

So with that I'd like, with your permission to have, Dr. Wright, offer his testimony.

Mr. WALGREN. Thank you. Dr. Wright?

Dr. WRIGHT. Thank you, Mr. Chairman.

Mr. WALGREN. Let me say at the outset too that your written statements will all be reproduced in the record for those who review these documents without more, and you can certainly feel free to focus on individual points that you want to underscore for the oral part of the record and that will help focus our attention if you can do that. Dr. Wright?

Dr. WRIGHT. Thank you, Mr. Chairman for the opportunity to discuss the international competitiveness of the construction industry, to highlight contributions of prior NBS work, and to outline plans for our future contributions responding to the challenges and opportunities for competitiveness in construction.

Mr. Chairman, you've already described the importance of the construction industry to the economy and quality of life and safety in the United States. I need not dwell on these points. I do want to emphasize that when we look realistically at our construction in-

dustry, we must understand that small enterprises dominate in construction.

The usual construction project involves a unique team. The owner, the architect, the structural engineer, the general contractor, specialty contractors, etc. Each of these participants may have several simultaneous projects but the team for each project usually never has worked together before and never will again. And in our plans for construction research at NBS we seek to serve the U.S. construction industry as it really exists.

Private sector R&D for construction focuses on product development for which research investments can be recouped in the marketplace. As Dr. Haviland will describe the results of his study for the National Academies, construction R&D is less than 4/10 of a percent of construction value and over 80 percent of it is funded by the private sector.

The U.S. construction industry faces growing international competition as some of the people will testify following my presentation. For several years construction industry groups have been concerned with the competitiveness sometimes expressing this as productivity or as quality of the U.S. construction industry.

Important reports have been issued by the Business Roundtable Construction Industry Cost Effectiveness Study. The American Society of Civil Engineers, the National Academies, and from a recent roundtable on keeping American construction competitive co-sponsored by Congressman Boehlert of this Committee.

These point out needs to improve management in the U.S. construction industry, to improve the economic and public policy environments for construction and to regain U.S. technical leadership. This technical leadership is required to overcome the cost advantages of low wage countries in conventional technologies, and to match advanced countries such as Japan that have been investing more in construction R&D.

Automation is needed to improve competitiveness in construction. Moreover the nature of the U.S. construction industry mandates open systems of hardware and software for successful automation in construction. Each participant in construction must procure and become skillful in the use of automated equipment such as computer hardware and software. Because the construction team is unique to each project it is not feasible to require participants to purchase and to learn to use a different specific system of hardware and software for each project.

Similarly, automated construction devices, whether design equipment or robots at the construction site, must be usable in association with an arbitrary use of automated and conventional technologies. Indeed, the situation for successful automation and construction is similar to the widely recognized needs for open systems for manufacturing and office automation.

Automation of the constructed facility itself, such as the intelligent office building, will be necessary to meet owners and users needs for efficient and productive facilities. Again, open systems are required for the hardware and software of an automated constructed facility. Then, an owner can consider alternative suppliers for the components of the initial system, mix manual and automat-

ed functions and upgrade the system incrementally as technologies and needs evolve.

Open systems also stimulate private sector innovation. An innovator can find a market for an improved product or service without having to create a complete, vertically and horizontally integrated system. For instance an improved thermostat immediately can be used in a variety of open systems for heating and air conditioning.

NBS building research has contributed effectively to maintaining open systems for building services and products and to stimulating innovations in the private sector for competitiveness. NBS produces non-proprietary technologies to predict and measure the performance of building materials, components, systems and practices that are used for responsible and cost effective decisions in construction.

NBS serves on about 200 national and international voluntary construction standards committees to transfer research of its own and of others to practice. My written testimony gives 9 examples to show how NBS research helps to improve U.S. construction practices and results in increased competitiveness in domestic and foreign construction markets.

Annual savings for these examples to the consumers of construction annually are more than 1,000 times the annual budget for the NBS construction research program. But these savings are not a result of NBS work alone. We work cooperatively with industry, universities, other government agencies, and those who will use the results to assure that the work is on target and timely.

NBS plans to focus research for the improvement of competitiveness in construction on computer integrated construction technologies needed for open systems of construction hardware and software. NBS will develop advanced measurements for diagnostics and quality assurance. These will improve abilities to control the operations of constructed facilities, assess existing facilities for maintenance or retrofit, and assure quality in manufacturing and construction in the construction site.

NBS will develop and validate techniques for modelling the performance of building materials, components or systems in the construction and in the service life environments. These will provide the bases for private sector development of computer programs used in the design construction and operation of constructed facilities. These also will provide ways to test complex hardware and software systems, such as energy management and control systems for buildings, without disclosing proprietary information.

To support the automation of facilities' operating systems NBS will develop improved performance models, information interface protocols, standards and calibrations for sensors and techniques to test control hardware and software.

For robotics in construction, NBS will develop measurement methods to define conditions at the building site, hierarchical control principles, information interface protocols, and measurement and test methods for the properties of hardware and software.

This work is conducted in cooperation with the NBS Center for Manufacturing Engineering to transfer to the construction industry the knowledge gained in the NBS automated manufacturing research facility for open systems of factory automation.

NBS will develop information interface protocols supporting automatic information exchange between computer systems of diverse construction participants. Also NBS will develop test methods for the consistency of data with other project information to detect and avoid interferences and errors.

NBS will develop techniques for formulation and testing of machine representations of engineering standards to provide computer aids for design or decision making in construction. We also will develop techniques for interfacing machine representations of standards to application programs. These will assure that the intent of the standards developing organization is followed in the machine representation and that computer programs readily can be used with the standards or codes applicable to a specific project.

Competitiveness in construction is significant because construction is a major U.S. industry contributing 8.9 percent of the gross national product, two-thirds of the nation's fixed reproducible wealth and effecting everyone's safety, productivity and quality of life.

Technical leadership is essential to U.S. competitiveness in construction. The public and the construction industry need open systems for automation of construction products and services that permit incremental automation and stimulate innovation in the private sector.

Research at NBS has contributed significantly to competitiveness in construction. We plan to contribute further by developing computer integrated construction technologies that facilitate open systems for automated construction products and services.

Unique NBS laboratory facilities are available for cooperative research with industry, universities, and other Federal agencies.

Thank you, Mr. Chairman. I'll be happy to respond to questions.

[The prepared statement of Dr. Richard N. Wright follows:]

U.S. DEPARTMENT OF COMMERCE
STATEMENT OF RICHARD N. WRIGHT, DIRECTOR
CENTER FOR BUILDING TECHNOLOGY
NATIONAL ENGINEERING LABORATORY
NATIONAL BUREAU OF STANDARDS
BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
ON RESEARCH AND COMPETITIVENESS IN THE CONSTRUCTION INDUSTRY

JUNE 4, 1987

1. INTRODUCTION

Thank you, Mr. Chairman, for the opportunity to discuss the international competitiveness of the construction industry and the role of the research of the National Bureau of Standards (NBS) with the Subcommittee and with other witnesses from the construction industry.

As director of the NBS Center for Building Technology (CBT) since 1974, I have been involved with its field, laboratory and analytical research programs for predicting, measuring and testing the performance of building materials, components, systems and practices. This knowledge is used throughout the building community to increase the usefulness, safety and economy of buildings. These are qualities vital to the competitiveness of the construction industry.

My related activities representing NBS have shaped my own perspectives on the research activities and competitiveness of the construction industry internationally. The International Council for Building Research, Studies and Documentation involves building research organizations from about 70 countries (western, eastern and developing) in international cooperation in building, housing and planning research. I was its president from 1983-86 and currently chair its Programme Committee. The U.S.-Japan Panel on Wind and Seismic Effects involves 15 U.S. and 9 Japanese agencies in sharing research findings and conducting cooperative programs for improving safety from extreme winds and earthquakes. I chair the U.S. side and returned on May 23 from a two week trip to Japan for the Panel's technical conference and study tour that looked at advanced design and construction practices in Japan. I have worked with the American Society of Civil Engineers (ASCE) on issues of productivity and quality in construction that are tightly linked to competitiveness and given high priority by ASCE. These activities include chairing the 1983 workshop on civil engineering productivity [1], serving on the steering committee for the 1984 workshop on Quality in the Constructed Project [2], and co-authoring the chapter on use of computers in design for the forthcoming Manual of Professional Practice for Quality in the Constructed Project. Also, I serve as liaison member for NBS to the National Academies' International Construction Study which is led by Dr. John Fisher, and served as steering committee member and keynote speaker for the April 1987 workshop "Construction Automation: Computer-Integrated

Construction" sponsored at Lehigh University by the National Science Foundation.

This testimony summarizes the situation in respect to international competitiveness of the U.S. construction industry. The record of NBS contributions to competitiveness is noted, and present, approved plans for NBS building research to contribute further to competitiveness of the construction industry are described.

2. COMPETITIVENESS OF THE U.S. CONSTRUCTION INDUSTRY

Construction is one of the Nation's largest industries. In 1986 [3], new construction put in place amounted to $375 billion, 8.9% of the GNP, providing jobs for more than 6.2 million persons. Constructed facilities shelter and support most human activities. Their quality affects the productivity of U.S. industry, and the safety and quality of life of the people. Moreover, the quality of construction strongly affects the wealth of the Nation; over two thirds of the Nations's fixed reproducible wealth is invested in constructed facilities [4].

Small enterprises predominate in construction. There is a unique team (owner, architect, structural engineer, general contractor, specialty contractors, etc.) for most construction projects. Each participant may have several simultaneous projects. The team for each project usually never has worked together before, and never will again.

Private sector R&D for construction focuses on product development for which research investments can be recouped in the marketplace. Because construction enterprises generally are small and lack resources for research, construction R&D is only .39 percent of construction value, but 82 percent of it is funded by the private sector [5].

The U.S. construction industry faces growing international competition [3]:

- U.S. share of international contracts declined from 41 to 35 percent from 1980 to 1985.
- Foreign-owned companies increased U.S. contracts from $3.6 to $7.3 billion from 1982 to 1985.
- The $272 million U.S. trade surplus in 1981 for nine construction materials became a $872 million deficit in 1985.

For several years, construction industry groups have been concerned with the competitiveness (sometimes expressed as productivity or quality) of the U.S. construction industry. Reports have been issued by the Business Roundtable Construction Industry Cost-Effectiveness Study [6], ASCE [1,2], the National Academies [5], and from a recent roundtable on keeping American construction competitive cosponsored by Congressman Boehlert [7]. These point out needs to: improve management

in the U.S. construction industry, improve the economic and public policy environments for construction, and regain U.S. technical leadership. Strengthened research and improvements in practice are required to overcome cost advantages for low-wage countries in conventional technologies, and technical and quality leadership gained by advanced countries, such as Japan, that have been investing more in construction R&D.

Automation must developed to improve competiveness in construction. The nature of the U.S. construction industry mandates open systems of hardware and software for successful automation in construction. (The term system here denotes an entire constructed facility, such as a building, or construction process, such as structural design. A system is considered closed if it requires the use of a specific set of components and no other components can be substituted. A system is considered open if it permits many different types of components to be used interchangeably.) Each participant in construction must procure and become skillful in the use of automated equipment such as computer hardware and software. Because the construction team is unique to each project, open systems are needed for the automatic exchange of information between participants [8]. It is not feasible to require participants to purchase and to learn to use a different specific system of hardware and software for each project. Similarly, automated construction devices, whether design equipment or robots at the construction site, must be usable in association with an arbitrary mix of automated and conventional technologies [9]. Indeed, the situation for successful automation in construction is similar to the widely-recognized needs for open systems for manufacturing and office automation.

Automation of the constructed facility (such as the intelligent building) will be necessary to meet owners' and users' needs for efficient and productive facilities. Again, open systems are required for the hardware and software of an automated facility [10]. In an open system, each component has well defined characteristics for information input and output, and for performance. An owner can consider alternative suppliers for components of the intial system, mix manual and automated functions, and upgrade the system incrementally as technologies and needs evolve.

Open systems also stimulate private sector innovation. An innovator can find a market for an improved product or service without having to create a complete, vertically and horizontally integrated system. For instance, an improved thermostat immediately can be used in a variety of heating and airconditioning systems.

3. CONTRIBUTIONS OF NBS TO COMPETITIVENESS IN CONSTRUCTION

NBS building research has contributed effectively to maintaining open systems for building services and products and to stimulating innovations in the private sector for competitiveness. NBS produces non-proprietary technologies to predict and measure the performance of building materials, components, systems and practices that are used for

responsible and cost effective decisions in construction. NBS serves on about 200 national and international voluntary standards committees to transfer research (of its own and of others') to practice. Examples follow.

Structural Reliability

Results of NBS research on occupancy, wind and earthquake loads, prediction of structural resistance, and structural reliability have received national recognition, and have been incorporated into national standards such as American National Standards Institute (ANSI) standard A58 "Minimum Design Loads for Buildings and Other Structures," to increase structural reliability and to reduce design costs.

Structural Failure Investigations

NBS investigated and reported on the physical causes of major structural failures, such as the 1981 walkway collapse in Kansas City that killed 113, the 1982 overpass failure in East Chicago that killed 13 construction workers, and the 1978 cooling tower collapse at Willow Island that killed 51 construction workers. At present, we are investigating the causes of the building collapse in Bridgeport, Connecticut in April that killed 28 workers. In failure investigations, our aim is to assure that the physical causes are publicly known and can be avoided in the future.

Seismic Design and Construction Standards

The private sector Building Seismic Safety Council (BSSC) cited NBS for its technical support in formulating nationally applicable, comprehensive seismic design provisions suitable for use in voluntary standards and building codes, and in conducting the trial design program that provided the basis for BSSC's recommendations of the provisions for adoption in national standards and model codes.

Rehabilitation Standards

At the request of the National Conference of States on Building Codes and Standards (NCSBCS) and the State of Massachusetts, NBS developed a more cost-effective approach to regulating building rehabilitation that has been adopted by Massachusetts and incorporated in rehabilitation guidelines of the Department of Housing and Urban Development. We also formulated methods for condition assessment of existing buildings that are being processed as a national standard by the American Society of Civil Engineers (ASCE).

Building Energy Conservation Standards

At the request of NCSBCS, NBS developed a technical approach for a nationally applicable energy conservation design standard for buildings that has been developed as a national standard by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and provides the basis for the energy building code requirements of all 50 states. A study by Arthur D. Little Co. showed that application of the standard saves about 50 percent of the space conditioning energy relative to practice prior to its development, and accomplishes this with a reduction in initial costs. Corresponding incremental, annual energy cost savings are in excess of $19 billion per year.

Insulation Measurements

NBS developed a 1000mm line source guarded hot plate to permit direct measurement of thermal insulation performance at thicknesses up to 15 inches (the earlier standard was 1 inch) and provided calibrated transfer specimens to manufacturers to allow them to meet labeling requirements without excessive uses of material. The U.S. Chamber of Commerce has attributed annual savings of $90 million to the availability of this measurement technology.

Appliance Efficiency

NBS developed test procedures for refrigerators, refrigerator-freezers, dishwashers, clothes washers, clothes dryers, water heaters, room air conditioners, home heating equipment, television sets, kitchen ranges and ovens, humidifiers and dehumidifiers, central air conditioners, and furnaces that are used by manufacturers to label their products. These test procedures have supported 10 to 50 percent increases in appliance efficiency, and the most efficient, innovative appliances now coming on the market provide additional efficiency increases of 50 to 100 percent.

Residential Plumbing Standards

NBS research on plumbing loads and the hydraulics of drainage and venting provided the technical bases for changes in the plumbing provisions of the One and Two Family Dwelling Code published in 1986 by the Council of American Building Officials. According to the National Association of Home Builders, the changes in plumbing provisions will save about $500 per dwelling unit, amounting to $500 million annually for a normal production of one million such dwelling units.

Corrosion-Resistant Reinforcing Steel

NBS developed performance criteria and test methods for the protection of reinforcing bars in concrete from salt-induced corrosion.

These have been incorporated into national standards, supported the development of a new industry producing coated reinforcing bars, and led to their use in most bridge decks in areas subjected to freezing weather. Federal Highway Administration findings indicate that service lives are extended to more than 40 years (from 5 to 10 without coating), which corresponds to annual savings in excess of $300 million.

These examples show that NBS research helps to improve U.S. construction practices, and results in increased competitiveness in domestic and foreign construction markets. The examples also illustrate that our work is conducted cooperatively with industry, universities, other governmental agencies, and those who will use the results to assure that the work is on target and timely.

3. NBS RESEARCH FOR COMPUTER-INTEGRATED CONSTRUCTION

NBS plans to focus research for the improvement of competitiveness in construction on computer-integrated construction technologies needed for open systems of construction hardware and software. NBS unique laboratory facilities are open for cooperative research with industry, universities and other Federal agencies. Descriptions of activities follow.

Advanced Measurements for Diagnostics and Quality Assurance

Exploit the potential of microcomputers to measure complex properties of materials, structures and equipment (including hardware and software) in real time in the field, factory or laboratory. These will improve abilities to control the operations of constructed facilities, assess existing facilities for maintenance or retrofit, and to assure quality in manufacturing or construction.

Performance Modeling and Prediction

Develop and validate reference algorithms for modeling the performance of building materials, components or systems in the construction and service environments. These provide the bases for private sector development of computer programs used in the analysis and design of constructed facilities, ways to test the validity of proprietary computer software without disclosing proprietary information, and techniques to assess the correctness of complex hardware and software systems such as energy management and control systems for buildings.

Automation of Facilities Operating Systems

Develop improved performance models, information interface protocols, standards and calibrations for sensors, and emulators to test control hardware and software.

Robotics in Construction

Develop measurement methods to define conditions at the building site, hierarchical control principles, information interface protocols, and measurement and test methods for properties of hardware and software. This work is conducted in cooperation with the NBS Center for Manufacturing Engineering to transfer to the construction industry the knowledge gained in the NBS Automated Manufacturing Research Facility for open systems of factory automation.

Information Interfaces for Integrated Computer-Aided Design, Construction and Operation

Develop information interface protocols supporting automatic information exchange between computer systems of diverse construction participants, or an individual participant and an integrated project information system. Aiso, develop test methods for the consistency of data with other project information to detect and avoid interferences and errors.

Machine Representations of Standards and Expert Systems

Develop techniques for formulation and testing of machine representations of engineering standards to provide computer aids for design or decision making in construction, and techniques for interfacing machine representations of standards to application programs. These will assure that the intent of the standards-developing organization is followed in the machine representation, and that computer programs for analysis and design in construction can be used with the standards or codes applicable to the specific project.

4. SUMMARY

Competitiveness in construction is significant because construction is a major U.S. industry contributing 8.9 percent of the GNP and two thirds of the Nation's fixed, reproducible wealth, and affecting everyone's safety, productivity and quality of life. Technical leadership is essential to U.S. competitiveness in construction, and is facilitated by open systems for automation of construction products and services that stimulate innovation in the private sector. NBS research provides performance prediction and measurement technologies for construction materials, components, systems and practices that have contributed significantly to competitiveness in construction. NBS plans to contribute further by developing computer-integrated construction technologies that stimulate private sector innovations for automation in the design, construction and operation of buildings and other constructed facilities. Unique NBS laboratory facilities are a resource open to cooperative research with industry, universities and other Federal agencies.

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RICHARD N. WRIGHT

Date of Birth: May 17, 1932

Birthplace: Syracuse, New York

Education: Degrees
Syracuse University, B.S., Civil Engineering, 1953
Syracuse University, M.S., Civil Engineering, 1955
University of Ilinois, Ph.D., Civil Engineering, 1962

Position:
Director, Center for Building Technology
National Engineering Laboratory
National Bureau of Standards

His professional experience includes: junior engineer with the Pennsylvania Railroad, 1953 to 1955; Instructor, assistant professor, associate professor and professor of civil engineering at the University of Illinois at Urbana from 1957 to 1974; and at the National Bureau of Standards, Chief of the Structures Section, Building Research Division 1971 to 1972, Deputy Director-Technical, Center for Building Technology, 1972 to 1973, and Director, Center for Building Technology 1974 to present.

The Center for Building Technology (CBT) is the national building research laboratory. It conducts laboratory, field and analytical research. It develops technologies to predict, measure and test the performance of building materials, components, systems and practices. It works cooperatively with other organizations, private and public, to improve building practices. CBT does not promulgate or enforce building standards or regulations, but its results are widely used in the building industry and adopted by private and governmental organizations that have standards and codes responsibilities. CBT programs include: computer integrated construction, structural safety, earthquake hazards reduction, building environment, quality of building materials, and cement hydration.

CBT has unique laboratory facilities and a staff of engineers and scientists of international reputation. Principal disciplines are structural, geotechnical, materials, mechanical and electrical engineering, physics, chemistry, architecture and behavioral sciences. Of the 100 professional staff members, 50 have earned doctoral degrees and 30 are registered engineers or architects. About 50 research associates sponsored by industry, visiting scholars from universities, and guest workers from foreign laboratories complement the professional staff.

Dr. Wright has published over 50 articles on computer aided design, formulation and expression of design criteria, performance criteria for buildings, structural design methods for earthquakes and other dynamic loads, flow and fracture in structural metals and mechanics of thin-walled beam structures.

He is President of the Liaison Committee of International Civil Engineering Organizations, Past President and Programme Committee Chairman of the International Council for Building Research, Studies and Documentation, Chairman of the Interagency Committee on Seismic Safety in Construction, U.S. Chairman of the U.S.-Japan Panel on Wind and Seismic Effects, fellow of the American Society of Civil Engineers, and member of the International Union of Testing and Research Laboratories for Materials and Structures, Earthquake Engineering Research Institute, Sigma Xi, Phi Kappa Phi, and Tau Beta Pi. He registered as a professional engineer in New York in 1958 and as a structural engineer in Illinois in 1974.

He received the Gold Medal Award of the Department of Commerce in 1982 for distinguished achievement in the Federal Service, and the Special Presidential Award of the Illuminating Engineering Society of North America in 1983 for contributions to the organization of the Lighting Research Institute.

Mr. WALGREN. Thank you, Dr. Wright. Let's then turn to Dr. Haviland.

Dr. HAVILAND. Thank you, Mr. Chairman.

I am David Haviland, Dean of the School of Architecture at Rensselaer Polytechnic Institute, and in 1985 it was my pleasure to chair the Committee on Construction Productivity of the Building Research Board of the National Academies of Science and Engineering. I recognize Henry Borger, Executive Director of the Federal Construction Council, a part of the Board, who is with us this morning and who played an integral role in compiling the data for the study.

My testimony this morning will present some key conclusions from the BRB's full report. Construction productivity: Proposed Actions by the Federal Government to Promote Efficiency in Construction. I respectfully request that it be made part of the hearing record.

Mr. WALGREN. Without objection.

Dr. HAVILAND. And I wouldn't be a good academic if I didn't have three or four charts of statistics with me this morning. Rather than try to show them on the screen over here I think what I would rather do is refer to them and they are included in my written testimony which I believe you have.

Let me review the key conclusions of the Building Research Board's study, some of which are self evident. Building is big business in this country. You know, in 1985, and I'm going to use 1985 data mostly because the study was done then, the Bureau of the Census placed the overall level of construction in this country at $313 billion. That number is now running as you pointed out in your opening comments almost $400 billion, and some in the industry estimate that this number, as good as it is, understates total construction by as much as $100 billion.

Whatever the number is, it's a very large one, and I think more to the point, building is pervasive. Every sector of our economy requires new and renovated facilities, and thus the productivity of the construction industry directly influences the productivity of every segment of the American economy. And concerns about international competitiveness exacerbate this concern.

Productivity in construction is not good. There is not agreement on how to best measure it. The Federal Government's own measure which is flawed and no longer published suggests dramatic decreases over the past 20 years, and I have included in the written testimony as Exhibit 6 a picture of the Bureau of Labor Statistics' Productivity Index which is the source of your comment earlier that in the last 20 years there has been a dramatic decline.

Now some analysts suggest that the situation is not quite as bad as that. There's quite a bit of debate about this, but the conclusion that we've reached from looking at all sectors of the debate is that construction productivity is poor. It's either getting poorer very quickly or maybe not so quickly, but at best it's not improving.

Now there are many reasons for productivity problems. Some are from within the industry. Some have to do with the external conditions under which the industry operates. Dr. Wright has mentioned some of them in his comments this morning and they are summarized in Exhibit 7 from our written testimony.

Investments in research and development are one of these problems, and generally investments in R&D are considered to be effective in improving productivity so the BRB committee on construction productivity focused on R&D in all of its forms, from basic research to demonstration and dissemination of what's known as a strategy for improving construction productivity in this country.

The total annual investment in R&D by all elements of the construction industry is low. Even an optimistic estimate, and we compiled as optimistic an estimate as we thought we could—one that counts as R&D work that is only marginally or peripherally related to construction—yields an annual estimate of just in excess of $1 billion. Our Exhibit 8 summarizes this. The total number on that exhibit is $1.2 billion. A microscopic portion of it is contributed by construction contractors. About $220 million from Federal agencies, and the remaining $800 million from manufacturers of construction products and equipment.

If you use these numbers and express them as a percentage of sales, the investment in R&D is .39 percent. Now over two-thirds of this R&D is done by manufacturers as I've pointed out, and I would also like to say that much of this investment is indirect. That is to say it's done in other industries for purposes other than construction and has second order benefits to construction.

When you look at these numbers, we conclude that the United States construction industry invests proportionately less in R&D than most other mature U.S. industries. Now we'll leave off for the moment the chip industries and those that have very high levels of R&D. If we simply look at the mature industries as we do in Exhibit 10 of our written testimony, construction at .39 percent ranks right down there with tobacco, steel and fuel, other industries that have their problems.

We also invest proportionately less than many other foreign countries. Based on the lack of increase in U.S. construction productivity over the last 20 years and the low rate of investment in R&D, our committee concluded the construction related R&D has been inadequate, and needs to be increased.

And further we concluded, that there is little reason to hope that the needed increase will come from the private sector. The existence of a construction productivity problem has been recognized and discussed for many years and yet the amount on R&D spent by private members of the construction community has remained low, and it was thus the conclusion of our committee that if there is to be an increase in construction R&D some direct actions by the Federal Government are required.

Now in this instance we believe that Federal action is appropriate. I should point out that when, again using 1985 data with an estimated $50 billion annual outlay in construction related expenditures, there is no larger stake holder in this problem than the Federal Government itself, and if you look at Exhibit 2 and 3 of our testimony those numbers are presented and I would point out that

this $50 billion figure does not include another approximately $80 billion in loan guarantees, grants, subsidies, insurance programs and other forms of Federal participation, financial participation in construction.

Now the Federal Government does now invest in construction R&D. You've heard Dr. Wright speak about the activities of the National Bureau of Standards. There are investments at the National Science Foundation, at many of the mission agencies that build. We estimate again using—and now 1984 data, that about $220 million can optimistically be considered as invested in construction R&D by Federal agencies. Again we're being optimistic. For example, we include in this number the entire civil engineering program at the National Science Foundation even though only a portion of that program directly affects construction.

This investment expressed again as a percentage of sales, is slightly higher than that for the country as a whole. It's .50 percent, and yet it's still low when compared to other areas of concern to the Federal Government. If you look at Exhibit 12 and compare the investments in construction with those in agriculture, natural resources, transportation and other areas, it is very close to the bottom of the list.

With all of this in mind, the Building Research Board Committee made 4 recommendations. The first is that the Congress should formally acknowledge the need for Federal leadership in conducting, funding and coordinating general construction related R&D just as it has in agriculture, medicine, transportation and other fields.

Secondly, in order to ensure impact, the program should be funded in a way that provides for stability and continuity. We did not propose a method for doing this. That is not our expertise, but yours, but we did look at what makes for a successful continuing research program and those conclusions are in our report.

In terms of dollars, let me give you this benchmark. A 1 percent surcharge on each Federal construction appropriation in 1984 would have generated approximately $440 million dollars for construction related research, a doubling of the Federal Government's commitment to construction R&D in that year.

Third, to ensure that a broad spectrum of construction R&D that attacks across the spectrum of the problems is done, we would recommend that program funds be distributed to 3 different kinds of agencies: Those that build in direct support of their missions, in fact the lion's share should go there of course. Those like the National Science Foundation and the National Bureau of Standards that support more generic R&D, and finally agencies like the Bureau of Labor Statistics and the Census for developing and publishing better measures and statistics. If we don't have better measures, we won't be able to measure impact, and as you well know, that will endanger the health of any program of investment that we might make.

And finally in formulating the program, the Congress should provide a mechanism to ensure that the construction R&D activities of the various Federal agencies are coordinated and that information

and technology produced through such activities are widely disseminated.

In summary we have both a problem and an opportunity here. Like everyone in the construction community, I appreciate the Subcommittee's willingness to tackle this issue and look forward to the fruits of your work.

Thank you very much.

[The prepared statement of Dr. David Haviland follows:]

Testimony
of

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before the

Subcommittee on Science, Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives

June 4, 1987

Mr. Chairman and Members of the Subcommittee, I am David S. Haviland, Dean of the School of Architecture at Rensselaer Polytechnic Institute. In 1985, it was my pleasure to chair the Committee on Construction Productivity, Building Research Board (BRB), Commission on Engineering and Technical Systems, National Research Council.

It is most appropriate that the Congress focus on the economic well-being and competitiveness of the American construction industry, and it is a pleasure to introduce the Subcommittee to the Building Research Board's work on R&D and construction productivity.

This testimony presents excerpts from the preface and executive summary of the BRB's report, as well as summaries of some of the important data presented in the report. The full report, Construction Productivity: Proposed Actions by the Federal Government to Promote Efficiency in Construction, is available from the National Academy Press, Washington, DC. This full report has been made available to the Subcommittee, and should be included as part of the hearing record.

Our Committeee on Construction Productivity included members from academia, government, and industry. A list of members, along with information about the sponsorship of the study, and the National Research Council, is appended to this testimony.

As we seek to best use our national resources and to maintain our international competitiveness, the productivity of the American economy is of major concern to all Americans.

Building--the planning, design and construction of new facilities as well the ongoing repair and rehabilitation of existing facilities--is especially important. We invest over $300 billion in newly-constructed homes, nonresidential buildings of all kinds, industrial and utility plants, highways and other transportation facilities each year. The productivity of the construction industry directly influences the productivity of every segment of the American economy.

A visit to any construction site, however, will confirm that building is a complex, slow and stubborn business. The products of the construction industry are bulky, complex and expensive. Most are one-of-a-kind designs and, in most cases, the factors of production must be brought to and assembled at a unique site. For each project a temporary multi-organization of people and firms who have different interests and values, who have not worked together, and may not work together again, is brought into being. It is no wonder that there have been so many allegations of low productivity in this critically important industry.

With an estimated $50 billion annual outlay in construction-related expenditures, there is no larger stake-holder in this problem than the federal government itself. Given this reality, the agencies that sponsor the Federal Construction Council asked the Building Research Board to determine what they can do, if anything, to stimulate increased productivity.

During the past two decades many individuals and organizations have expressed alarm about an apparent decline in the productivity of the U.S construction industry, and there have been numerous calls for the federal government to take action to reverse the trend.

The federal agencies that sponsor the Federal Construction Council asked the Building Research Board to assemble a committee of knowledgeable individuals to assess the current state of technology and research related to construction productivity in the United States and to explore the possible roles of federal construction agencies in fostering research and the development of new construction techniques. The committee was formed and conducted its investigation during calendar year 1985. This report presents the results of the committee's work.

The committee affirmed that the federal government has a legitimate interest in the health and productivity of the construction industry, both because the industry is a huge and vitally important element of the national economy (it accounts for more than 8 percent of the gross national product and has a major impact on most other elements of the economy) and because

the federal government funds a significant percentage of all U.S. construction work. The committee also affirmed, however, that the construction industry is highly decentralized and complex and is not easily influenced by federal action.

EXHIBIT 1 summarizes the impact of building and nonbuilding (heavy, process, highway) construction on the nation's economy. Many in the industry feel that government data underestimate the amount of construction, especially when one considers major repairs and owner-accomplished construction.

EXHIBITS 2, 3 and 4 summarize the federal government's role as purchaser, granter, lender, insurer and guarantor of construction in the United States.

On the basis of a review of the literature and its own analysis, the committee found that it is difficult to show conclusively that construction productivity has actually decreased in recent years or, if it has decreased, to show the magnitude of the decrease. However, most evidence suggests that even if construction productivity has not actually decreased, it probably s not increased very much either. Furthermore, it is almost hat productivity growth in construction has been slower ies in the United States.

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e Bureau of Labor Statistics
on productivity index.

The committee concluded that although there is a need for more comprehensive and accurate measurement of construction productivity, efforts to improve productivity need not be deferred until more accurate estimates are available. There is already sufficient evidence that a productivity problem exists to justify action.

Because it has been clearly demonstrated that, as a general rule, productivity is increased through investments in R&D, one of the reasons often given for the current productivity problems of the construction industry is insufficient R&D.

Various economic and sociological factors that are outside the control of the construction community have been cited as reasons for the productivity problems of the construction industry (e.g., fluctuations in interest rates, a shift in the nature of the output of the construction industry, and a drop in the average age of construction workers). While such factors probably have contributed to the productivity problem, the committee has focused on the technical and managerial aspects of the construction process itself (i.e., the planning, design, and construction of buildings and similar facilities) because that was its charge and out of conviction that problems with the construction process have been the major cause of the productivity problems, though possibly not the only cause.

EXHIBIT 7 lists some of the factors commonly cited as responsible for low construction productivity.

6

On the basis of its analysis of construction R&D, the committee determined that:

o The total annual investment in R&D by all elements of the construction community probably amounts to about 0.39 percent of the annual value of construction put in place. Manufacturers of construction materials, products, and equipment probably account for almost 69 percent of all construction-related R&D in the United States, government agencies for about 18 percent, contractors for about 4 percent, and all other elements of the building community (e.g., labor unions, architects, and various engineering disciplines) for about 9 percent.

EXHIBIT 8 provides the Committee's admittedly optimistic estimates of the amount of construction R&D in 1985.

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o Much of this investment is indirect, done by other industry for other purposes, with second-order benefits to construction.

EXHIBIT 9 looks at these second-order benefits. Converting the total shown into 1984 dollars yields the $ 838 million shown in Exhibit 8.

7

o The U.S. construction community, including users, manufacturers, contractors, government agencies, and others, probably invests proportionally less in R&D than other U.S. industries and also less than the construction industries in many foreign countries.

EXHIBIT 10 compares R&D investments in construction with those in other "mature" American industries.

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o The federal government invests less in construction R&D than in R&D in other fields.

EXHIBIT 11 summarizes federal research investments--some of which are only peripheral to constructior--and EXHIBIT 12 compares them to investments in other areas.

Based on the lack of increase in U.S. construction productivity over the past 20 years and the low rate of investment in construction-related R&D, the committee concluded that construction-related R&D has been inadequate in the United States and needs to be increased. Because of the complexity and diversity of the construction industry, it is impossible to determine precisely how much of an increase in R&D is needed. It is apparent, however, that the current level of investments in R&D is sufficiently low that the amount of R&D could easily be increased several fold before the point of diminishing returns is reached.

The committee also concluded that there is little reason to hope that the needed increase will come from the private sector. Although the existence of a construction productivity problem has been recognized and discussed for many years, the amount spent on R&D by private members of the construction community has remained low. It seems unlikely that the factors that have caused this situation would change now. Therefore, if there is to be an increase in construction R&D, some direct action by the federal government will be required.

As part of its review of construction-related R&D in the United States, the committee explored whether the current supply of researchers would permit an expanded R&D effort. The committee concluded that while an increase in spending for construction-related R&D might produce a temporary shortage of researchers in various fields who are familiar with the construction process, the shortage would not persist for very long.

The committee next reviewed the history of previous government efforts to promote technological innovation to determine what type of federal construction R&D program (if any) might succeed. The committee concluded that with currently available statistics and analytical tools, it is impossible to determine in terms of macro-economics how federal R&D programs affect the overall economy. Most economists seem to believe intuitively that such programs are beneficial; however, they cannot prove it. Most also believe that federal R&D expenditures do not cause a decrease in private R&D investments.

The committee also found that the results of previous and ongoing federal R&D programs are varied. Some programs have been highly successful; others have failed. Whether a program succeeds or fails seems to depend more on nontechnical considerations than technical ones. Where a federal construction-related R&D program is carefully crafted, it has a good chance of succeeding.

The keys to a successful federal R&D program, the committee concluded, are the following:

- Involve representatives of all segments of the building community in the process of formulating the program and design the program to address a broad spectrum of needs. For example, the concerns of federal agencies that procure buildings as well as those of agencies that are interested in broader issues should be recognized.

- Concentrate on generic (non-proprietary) problems, opportunities, and issues; avoid involvement in the design, development, manufacturing, or marketing of proprietary products or concepts.

- Try to get a long term commitment to the program from Congress.

- Design the program to generate numerous small payoffs over an indefinite period of time; do not promise big results quickly.

- Design the program to cover the full spectrum of R&D projects, from the discovery of new basic knowledge to the

development of better methods of disseminating known technology.

- Design the program to permit researchers and research organizations from various segments of the industry to participate.

- Include a mechanism for promoting continuous two-way communications between users of technology (e.g., owners, contractors, designers) and researchers. R&D is of little value if it does not address real problems and important issues and if the results are not widely disseminated.

- Keep the size of the program large enough to ensure that many members of the building community can be involved and that the results of R&D will have widespread inpact, but not so large that it becomes a target for budget cutting.

- Find a mechanism for funding the program that helps give it stability and continuity.

The committee also concluded that it would be unrealistic to expect operational agencies to take the lead in performing or funding R&D of a generic nature. Agencies are under almost constant pressure to reduce budgets and expenditures, and most are unwilling to try to defend requests for funds that are not clearly related to their missions. Therefore, the committee concluded that the initiative would have to come from the Congress, and toward this end it offered the following recommendations:

1. The Congress should formally acknowledge the need for federal leadership in conducting, funding, and coordinating general construction-related R&D, just as it has in agriculture, medicine, transportation, and many other fields. This acknowledged leadership should be reflected in a federal program.

2. In order to ensure the stability of the program, the Congress should consider methods of funding a strong federal R&D program that would provide stability and continuity. Numerous options are available. Congress might consider, for example, providing multi-year authorization and appropriation for the program, establishing a program trust fund of some type, or funding the program through an automatic surcharge on all federal construction appropriations--like the approach that has been used for many years to fund highway research and planning.*

*In FY 1984 the federal government spent a total of almost $44 billion on construction (see Chapter 3). If, for example, a 1.0 percent surcharge had been added to each construction appropriation that year, approximately $440 million would have been generated for construction related research. Inasmuch as federal agencies actually spent about $220 million in FY 1984 on construction R&D, the 1.0 percent surcharge would have increased the FY 1984 budget by only $220 million.

3. In order to ensure that a broad spectrum of construction R&D needs are met, the Congress should provide for the distribution of program funds to the various federal agencies that have construction-related responsibilities; for example, some funds could be allocated to the agencies that are responsible for procuring federal facilities for R&D on the design and construction of such facilities, some funds could be allocated to agencies like the National Bureau of Standards and the National Science Foundation for generic R&D for the entire construction community, and some funds could be allocated to information-generating agencies like the Bureau of the Census and the Bureau of Labor Statistics for the development and publication of more accurate construction statistics.

4. In formulating the program, the Congress should provide a mechanism to ensure that the construction R&D activities of the various federal agencies are coordinated and that information and technology produced through such activities are widely disseminated. To accomplish this, the Congress might consider giving a particular agency overall responsibility for managing the program and distributing R&D funds to other agencies. Alternatively, Congress might permit the various agencies to manage their own R&D programs, but require them to participate in a cooperative, coordination body (either public or private) that would do for construction R&D what the National Research Council's Transportation Research Board has done for highway research for many years.

Exhibit 1

CONSTRUCTION: A MAJOR UNDERTAKING

- $ 313 BILLION IN NEW CONSTRUCTION PUT IN PLACE (Census, 1985)
- 8.5% OF THE GNP (Commerce, 1984)
- PROBABLY 8.6 MILLION WORKERS (extrapolation of BLS data, 1985)

These figures may be conservative; another $ 100 billion may be involved.

Exhibit 2

THE FEDERAL ROLE (1984)

DIRECT PURCHASES	$ 11 B
GRANT-IN-AID PROGRAMS*	21 B
CONSTRUCTION LOAN PROGRAMS **	12 B
1984 ACTUAL	$ 44 B
1985 ESTIMATE	$ 51 B

* e.g., highways, airports, community development

** e.g., small business, housing, electrification

Exhibit 3

THE FEDERAL ROLE (1984)

15% OF NEW CONSTRUCTION PUT IN PLACE

65% OF ALL NEW PUBLIC WORKS CONSTRUCTION

56% OF STATE AND LOCAL PUBLIC CONSTRUCTION

5% OF PRIVATE-SECTOR CONSTRUCTION

5% OF ALL FEDERAL SPENDING

Exhibit 4

THE FEDERAL ROLE (1984)

ALSO:

+ $ 39 B INDIRECTLY OR PARTIALLY RELATED TO CONSTRUCTION, e.g.,

  Revenue-sharing grants
  Subsidized housing
  GSA real property ops
  Flood insurance fund
  Farm ownership loans

+ $ 44 B IN LOAN GUARANTEES

  Housing
  Energy resources dev't
  Rural electrification

Exhibit 5

PRODUCTIVITY

$$= \frac{\text{OUTPUTS}}{\text{INPUTS}}$$

BLS (UNPUBLISHED) CONSTRUCTION PRODUCTIVITY INDEX:

$$= \frac{\text{Value added (revenues - expenses for materials and subcontracting) for SIC "Construction"}}{\text{Labor hours for these establishments}}$$

Exhibit 6

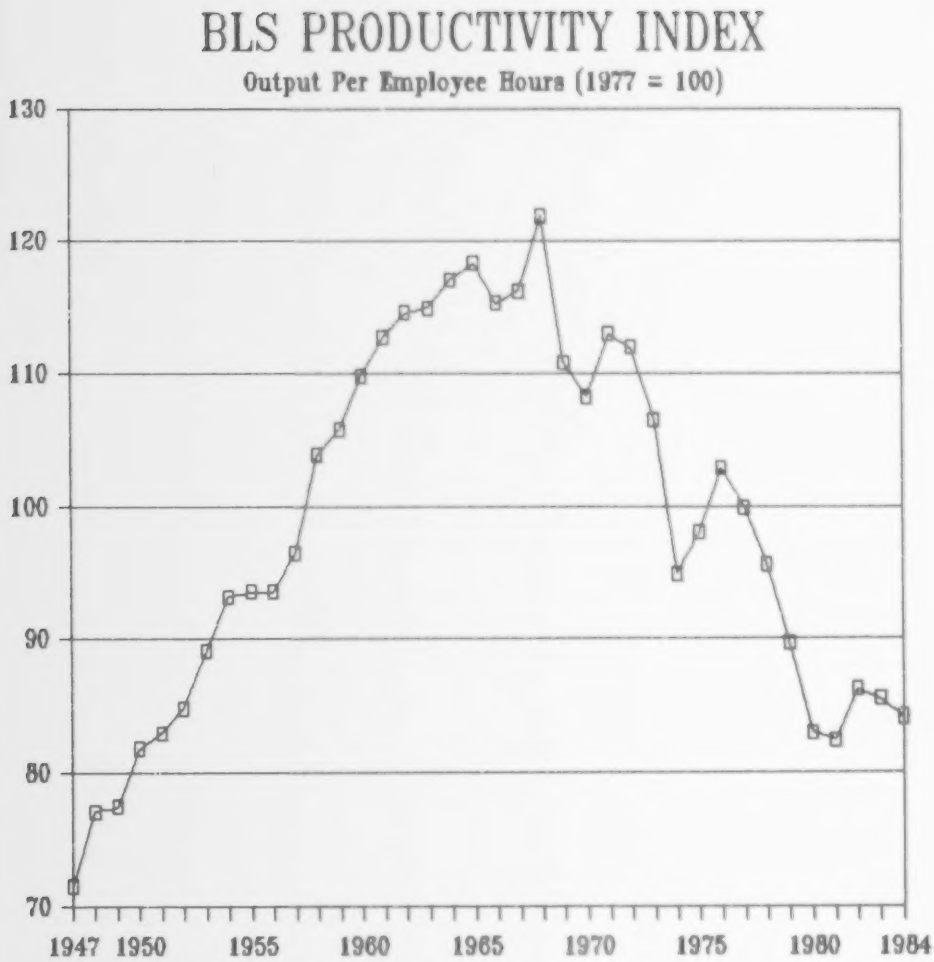
BLS PRODUCTIVITY INDEX
Output Per Employee Hours (1977 = 100)
130
120
110
100
90
80
70
1947
1950
1955
1960
1965
1970
1975
1980
1984

Exhibit 7

SOME PRODUCTIVITY PROBLEMS

NADEQUATE R&D

Lack of capital investment

Fragmentation of the industry

Out-of-date management practices

Undertrained workers (especially foremen)

Slow adoption of new technology

Jusridictional disputes

Government regulations

Exhibit 8

CONSTRUCTION R&D (1985)
(COMMITTEE ESTIMATES)

CONSTRUCTION CONTRACTORS	$ .054 B
MANUFACTURERS OF CONSTRUCTION PRODUCTS, EQUIP'T	.838 B
FEDERAL AGENCIES	.220 B
SUBTOTAL	$ 1.112 B
ALL OTHERS (@ 10%)	.111 B
TOTAL	$ 1.223 B
CONSTRUCTION PUT IN PLACE	$ 312.9 B
R&D AS PERCENT	0.39 %

Exhibit 9

R & D BENEFITTING CONSTRUCTION INDUSTRY - 1972 $ (Scherer)

Construction mining & materials handling equipment	$ 154.4 M
Motor vehicles	125.1 M
Other machinery	20.5 M
Fabricated metal products	17.1 M
Paints, explosives, toiletries & other chemical products	16.3 M
Radio & communication equipment	16.1 M
Measuring, medical & photo instruments	13.9 M
Engines and turbines	10.2 M
Construction	2.2 M
All others	56.2 M
Total	$ 432.0 M

Exhibit 10

R & D AS PERCENT OF SALES FOR SOME MATURE INDUSTRIES

CONSTRUCTION	0.39 %
Tobacco	0.4 %
Steel	0.5 %
Fuel	0.7 %
Textiles & Apparel	0.8 %
Food & Beverage	0.9 %
Containers	0.9 %
Paper	1.0 %
Appliances	1.4 %
Automotive	1.7 %
Oil service & supply	2.9 %

Business Week 1985 figures for nonconstruction industries

Exhibit 11

FEDERAL CONSTRUCTION-RELATED
R & D ESTIMATES (1984)

Procuring Agencies:	
ARMY CORPS OF ENGS	$ 42.7 M
AIR FORCE CIV ENG	33.0 M
DEPT OF ENERGY	32.2 M
ALL OTHERS	11.2 M
Total	$ 119.3 M
Other Agencies:	
NSF	$ 29.1 M
EPA	22.0 M
UMTA	17.8 M
FAA	8.1 M
NBS	6.7 M
USGS	4.6 M
FHWA*	2.5 M
ALL OTHERS	10.0 M
Total	$ 100.8 M

* plus $30 million transferred to states

Exhibit 12

FEDERAL R & D INVESTMENTS

CONSTRUCTION	$ .22 B
Education, training, employment, social services	.20 B
Agriculture	.76 B
Natural resources, environment	.96 B
Trainsportation	1.04 B
General science	1.68 B
Space	2.30 B
Energy	2.58 B
Health-related	4.78 B
Defense	29.29 B
As percentage of Federal investment in construction	.50 %

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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HONORS. AIA School Medal and McKinney Prize in Literature (at RPI); Who's Who in America.

March 1987

Mr. WALGREN. Thank you, Dr. Haviland.

Okay, and then we'll turn to Dr. Moavenzadeh. Is that how you say that? Very good.

Dr. MOAVENZADEH. Thank you. My name is Fred Moavenzadeh of M.I.T. and as you mentioned the construction industry plays a vital and highly visible role in the daily life of our nation. But despite its importance to the national economy and well being, the construction industry has not succeeded in mobilizing public understanding of and response to its needs. As a result, questions have arisen regarding the industry's competitiveness, its productivity and its ability to meet the demands for construction into the next century.

As far as productivity is concerned, yourself and my colleagues so far have indicated that construction has shown an alarming drop in productivity over the past 20 years. However if you look at the figures from 1920 to early 1960s we see that construction productivity grew at a healthy rate of 3.4 percent per year.

This sizeable increase in productivity and corresponding decrease in the real cost of construction during that period from 1920 to early 1960s were brought about primarily by mechanization of construction technology. The primary motivation behind this technological advance appears to have been the expansion and stability of the highway construction market beginning with the enactment of the Federal Aid Program of 1916 and culminating with the passage of the Highway Trust Fund in 1956.

As far as the industry's competitiveness is concerned, both internationally and domestically, several reasons have been advanced to explain our declining share of the world market and the stiff competition at home.

Among those most prominently mentioned in the trade press are U.S. Government policies in trade, taxation, financing, legal restrictions and marketing. All of these positions are pertinent in that they state what changes are necessary to equalize the rules of U.S. entry into the international construction market.

However, while the implications of these findings and recommendations for U.S. competitiveness cannot be denied, it is wrong to regard them as the fundamental causes of loss of U.S. leadership in construction worldwide.

External restrictions do affect a company's operations, profitability and competitiveness. Nonetheless, the ability of an industry to exercise worldwide leadership must depend on its internal strengths, not on external props.

In the U.S. the construction industry—in the U.S. construction industry that traditional strength is technology. For the industry to overcome competitive barriers worldwide it must regain and reassert its technological preeminence. Unless the U.S. construction industry improves its technological standing significantly, it is in danger of being overtaken by the international competition before the end of this century.

This brings me to my main concern, namely, the lack of research and development in construction. As it was mentioned by both Dr. Wright and Dr. Haviland, there is a paucity of reliable data on R&D in the construction industry. Both experience and what limited data are available however, suggests that construction R&D

needs to be strengthened in several respects, in level of effort, in sources of funding, and in nature of research.

A major concern, however, is not so much the paucity of R&D funding as it is on complete lack of attention to basic research. There is a great disparity between research support for basic dramatically different and highly innovative research efforts which leads to fundamental technological breakthroughs and research support for gradual piecemeal and marginal improvements in existing technology which leads to incremental advances in the state of the art.

Furthermore, there seems to be a great concern not so much over which branch of research to conduct, but rather which one provides the better foundation for the reemergence of U.S. leadership in construction. It is the premise of my argument that fundamental high payoff, medium term research has been clearly lacking in construction and needs to be encouraged. Worldwide leadership in construction must depend upon breakthroughs in construction technology. That is quantum leap of improvements in the ways in which construction is carried out.

One also can not overlook the research strategies of foreign competition. A dramatic example is Japan's recent thrust to shift from incremental technological advances and modest though commercially important adaptations of American and European inventions to a basic research phase and the achievement of world technological supremacy by generating a burst of original technological breakthroughs.

Achieving technological leadership in this way comes of course at a price. The research needed to produce a leap in technology is risky, takes time, is expensive and requires a steady commitment by the concerned parties. Nevertheless there are very strong reasons for arguing that the U.S. construction industry is uniquely situated to avail itself of this type of research and that such a research program should be initiated.

The model for such a major technological advance in construction is similar to the 1920s where the confluence of 2 major circumstances. One technologically driven, the other market driven resulted in mechanization of construction. The technologically driven trend was the growth of mechanization to replace animal and human powered equipment. The market driven trend however was the growth of the U.S. highway program as I mentioned earlier.

A parallel situation exists today. There is a need for the U.S. construction industry to reestablish its technological preeminence and to regain its competitiveness worldwide. At the same time a major new market in infrastructure has been identified for the construction industry. A market which is supposed to be $1–2 trillion.

Simultaneously a revolution is taking place in fields of technology having significant potential application to construction. I believe that a process similar to the mechanization of construction that took place in the 1920s which increased construction productivity several fold can occur again.

We are currently poised for a similar breakthrough. Computers, especially in the form of artificial intelligence and knowledge based systems, automation, robotics, remote sensing and remote control and engineered synthetic materials have advanced far enough that

they are poised to penetrate the construction industry and create an exciting new era in construction.

Three major economic powers in the world today, the U.S., Japan, and Western Europe are capable of making this transformation. It is my opinion that if the U.S. does not move fast we will fall behind. At the moment we are at the starting point in this race. The question is, are we ready for it?

Thank you.

Mr. WALGREN. Thank you very much, and we'll then turn to Dr. Fisher.

Dr. FISHER. Thank you, Mr. Chairman. I am thankful for your invitation to be here and to address you on this issue on research and competitiveness in the construction industry.

I am Professor of Civil Engineering at Lehigh University and Director of the Engineering Research Center Advanced Technology for Large Structural Systems, and my remarks this morning are based in large part on my perspective from my own research work in the position as Director of that center. They're addressing only some of the issues that you raise in your letter to us.

I'd like to start with the fact that during the last 10 years there have been some very major structural failures commencing in Orlando with the failure of a major truss in the Orlando Civic Center. That same year the Hyatt Regency Hotel in Kansas City collapsed. In 1985 here in the Washington area, Virginia's Wolf Trap Performing Arts Center had a major failure because of lack of knowledge about welds and more recently the Seattle Convention Center has had some experienced difficulties with large shapes.

I think in large measure all of these can be attributed to an inadequate knowledge base and without this knowledge base we can not expect to be properly designing and building structures nor detecting their changing service conditions, and as a result many companies have spent time and money on costly repairs, expensive and damaging litigation, increased insurance rates and wasteful delays of the project.

I think we in effect are investing at the wrong end of the process. Rather than developing research providing technology transfer and creating more reliable systems, we are spending millions of dollars on cures after the fact.

In the statistics that you've had brought before you this morning, it's been noted that the construction industry contributes about four-tenths of its gross billings to research in a broad and very liberally defined sense. This is a fraction, particularly if we look at contractors, architects and engineers who in that group contribute less than 5 hundreds of a percent, they're spending in excess of 4 percent on liability insurance. And it's interesting to observe also as has been pointed out that the major Japanese construction firms are each investing more in research and development than our total private sector.

Our own efforts in the engineering research center to obtain industry support in fact very closely parallels the points, the statistics that were brought out by Dr. Haviland. Most of our funds are in fact coming from the construction fabricating or steel industry. That is, the suppliers and not the contractors and engineers. So our

own experience in this short term has verified the statistics that were brought forth.

Now because it is a fragmented industry with no prior record of research and development, the general attitude is that others will supply the technology when it's needed and this is never going to resolve the problems and can only further jeopardize our competitive position.

In fact, I think it suggests that there has to be new financing mechanisms for the construction research and development. With a fragmented industry, no one is willing to support it, and innovative mechanisms are needed and I think the Federal Government has got to provide the leadership if this is to be a reality.

As an example, I'd like to illustrate that there are consequences of failing to carry out research and development and in fact, I think this is in large measure what Dr. Moavenzadeh has indicated. The reason there has been so much focused research rather than exploratory. If we just look for example at the electroslag welding process and its use in bridge structures. This process was introduced into the United States from Russian research and development, and was put into use in the 1960s. The Russian work did not address the issue of inspection, fatigue behavior and other performance conditions which must be considered in bridge applications.

Hence we introduced the process in the United States practice without significant work on these issues. Fracture of the I-79 bridge in Pittsburgh in 1977 led to the process being banned here in the United States by the Federal Highway Administration for tension applications.

Today 10 years later, much of our knowledge of the characteristics of the process has come from evaluating the problems that were discovered on various bridges. There has only been limited work carried out on how to improve the process and its toughness characteristics, how to inspect the weldments and how to ensure that they're crack free and whether or not these members are suitable with that connection method and are fatigue crack resistant.

So we're spending millions of dollars on repairs, on crash research on the material and fractures, on litigation and delays. And how much better it would have been to put some of that economic waste into a well planned research and development program.

The industry is very labor intensive, and hence I think there are these new technologies that Dr. Moavenzadeh has indicated. For example, computer based integration in the manufacturing industries is well underway in our country. However there is no effort of any significance currently underway in the U.S. construction industry. This technology needs to be developed through systematic research.

The fact is that the automation and robotics at manufacturing plants and on the construction site will only become a reality with effective methods that have to be very carefully researched. For example, the Japanese and the Germans have had significant work on smart cranes. And the Japanese towing machinery are examples of offshore R&D in these areas that we frequently have only put into practice after we can purchase it from them.

Now there is a need to improve technology transfer, based on research and teaching, and to make this transfer broadly across the industry and government. And we need to do the research here in the United States and we have to develop a more effective technology transfer program to put the research into practice.

Furthermore, I think it should be noted that research and development at universities is the primary means we have of educating engineers that are needed to develop and implement new technologies in the construction industry. We must be as dedicated to that goal as the Japanese are.

Thank you for the opportunity.

[The prepared statement of Dr. John Fisher follows:]

IMPROVING CONSTRUCTION RELIABILITY AND COMPETITIVENESS THROUGH RESEARCH AND DEVELOPMENT

JOHN W. FISHER

Professor of Civil Engineering
and Director, NSF Engineering Research Center
on Advanced Technology for Large Structural Systems (ATLSS)
Lehigh University

I am Dr. John W. Fisher from Lehigh University where I am Professor of Civil Engineering and Director of the NSF Engineering Research Center, Advanced Technology for Large Structural Systems. I am pleased to be here today, and thank you for the invitation.

I've entitled my remarks, Improving Construction Reliability and Competitiveness Through Research and Development. I've developed this perspective from my own research work and my position as Director of the NSF ATLSS Engineering Research Center.

Without strengthening its knowledge base, our fundamental understanding of the behavior of structures, America's construction industry may be courting disaster -- while spending millions on repair and litigation.

In 1981, at the Orlando Civic Center, a large jumbo section in a truss tension chord cracked during construction. That same year, at the Hyatt Regency in Kansas City, the collapse of a walkway resulted in a major and tragic loss of life.

In 1985, at Virginia's Wolf Trap Performing Arts Center, lack of knowledge about welds contributed to the fracture of a girder. And, more recently, the Seattle Convention Center difficulties with large jumbo sections in trusses.

These structural failures can be traced to an inadequate knowledge base. Without this base you cannot properly design or build structures nor detect changing service conditions. As a result, many companies have spent time and money on costly repairs, expensive and damaging litigation, increased insurance rates and wasteful delays in projects.

We are investing in the wrong end of the process. Rather than investing in research, development and technology transfer projects to create more reliable structures and prevent problems, we are spending millions of dollars on "cures" -- after the fact.

The problems with our structural systems are also reflected in the country's general economic condition.

Recent reports indicate that America's lead in international competitiveness has eroded. From traditional industrial productivity and technology development, to financial leadership, to education and research and to business strategy and execution, we as a nation, are falling behind.

In terms of education and research we know that Japan places a higher priority on engineering and science education.

- Japan, West Germany, and France are now spending a greater percent of their GNP on civilian research and development than the U.S. and 80 percent of research in Japan is funded by industry. By contrast, industrial research laboratories in the United States are closing almost daily, and instructional and research equipment in U.S. colleges and universities is seriously outdated.

In terms of business strategy and execution --

- Japanese government, education, labor, and industry work as close partners. Strategic planning and resource allocation is closely coordinated and targeted for maximum impact. Whereas our industry, labor and government are often adversaries, and education is not focused on industry needs.

- Leaders in Japan and elsewhere take the long view, but many U.S. executives and policy makers continue to emphasize the next quarter.

Meeting the Research and Development needs of the construction industry is necessary to improve reliability and enhance our international industrial competitiveness. The industry is facing serious competition from foreign firms in both the foreign and domestic markets. In the domestic market there has been dramatic growth in foreign competition. Foreign contractor awards rose from about 500 million dollars in the 70's to nearly 10 billion dollars in 1986.

As many of you know, foreign competition is directly impacting the construction industry. The Luling Bridge, which crosses the Mississippi at New Orleans, was fabricated into modular components in Japan with Japanese material and labor. These components were shipped to the U.S. in Japanese ships and erected with the aid of Japanese engineers. This is not a unique situation -- the Seattle Convention Center steel structure was fabricated in Taiwan from Japanese material and shipped here for erection.

U.S. structures-related industries as a whole account for more than $300 billion annually in the domestic market, employ about five million workers and professionals and are responsible for 7.5% of the gross

national product. It involves 75,000 design firms and one million general contractors. Yet, current U.S. construction related research and developments by all elements of the construction community is less than 0.4% of sales. Contractors, architects, and engineers contribute less than 0.05% as a group. This is a fraction of the amount spent on liability insurance. It's interesting to observe that some of the major Japanese construction firms are each investing more in research and development than our total private sector.

One of the tools that will be used to strengthen U.S. competitiveness in the structures-related industries is the work of the Engineering Research Center for Advanced Technology for Large Structural Systems. The National Science Foundation awarded this National Center ATLSS to Lehigh University in May 1986.

NSF funding for this Center is 1.4 million dollars during first year and will total 10.4 million dollars over five years. This is only one component of the Center's funding -- Pennsylvania's Ben Franklin Partnership Program will contribute three million dollars over five years. Lehigh University and the State of Pennsylvania have also contributed five million dollars for facilities. Pennsylvania has shown national leadership by recognizing the need and actively supporting research and development in this area.

However, our efforts to obtain industry support have met with limited success. We obtained about $100,000 during the first year and expect to have industry contribute about $300,000 during our second year. Most of these funds have been contributed by suppliers such as the steel industry and fabricators. This is compatible with the distribution reported in the

recent National Research Council Report by the Committee on Construction Productivity. In that report it was noted that suppliers of construction products provide about 70% of the funds used for construction research and development.

Because it is a fragmented industry with no prior record of research and development, the general attitude is that others will supply the technology when it is needed. This will never resolve the problem and can only further jeoporadize our competitive position. It suggests that a new financing mechanism must be developed for construction research and development. With a fragmented industry, no one is willing to support research and development, because they do not see a mechanism to capture the benefits of research and development. Innovative mechanisms are needed to support research and development and the federal government needs to provide the leadership if this is to become a reality.

There are two examples where I have been directly involved that I believe illustrate the point I want to make on the consequences of failing to carry out research and development before extensive use is made of the product or process.

The first example is the electroslag welding process and its use in bridge structures. This process was introduced into the United States from Russian research and development and was put into use in the 1960's. The Russian work did not address the issues of inspection, fatigue behavior and other performance conditions which must be considered in bridge applications. Hence, the process was introduced into U.S. practice without significant work on these issues. Fracture of the I79 bridge in Pittsburgh in 1977 led to the process being banned from use in tension applications by

the Federal Highway Administration. Today ten years later, much of our knowledge of the characteristics of the process has come from evaluating the problems that were discovered on various bridges. There has been only limited work carried out on how to improve the process and toughness characteristics, how to inspect the weldments to insure that they are crackfree, and whether or not large scale members using this connection method are fatigue crack resistant.

The second example is the large jumbo section that I cited as cracking at the Orlando Civic Center in 1981 and at the Seattle Convention Center in 1986-87. The heavy wide-flange shapes were originally developed for use as columns in the 1960's. These are members primarily loaded in compression. However, the availablility of the members led to their use in long span or heavily loaded trusses, even though research on their behavior and methods to connect them was not available. Once again extensive use was made of these sections in trusses with very little knowledge of their material characteristics. Only after the fracture at Orlando was work carried out that became generally available to the engineering profession indicating that they should not be used with welded connections. Unfortunately, these studies were carried out during the last four years after these problems developed and too late to prevent delay and economic waste.

In both of the examples cited, millions of dollars have been spent for repair, the crash research on the material and fractures, litigation and delays. How much better it would have been to put some of this economic waste into well planned research and development.

There are new technologies that provide the possibility of major breakthroughs in the construction industry. For example, computer based

integration in the manufacturing industries is being developed and pursued. However, little effort is currently underway in the U.S. construction industry. This technology needs to be developed through systematic research.

The industry is labor intensive and time waiting is wasted. Knowledge-based expert systems can provide a mechanism for improving communications and the efficiency and effectiveness of fabrication and construction activities.

Connections are generally the key to a structures behavior and performance. Yet our knowledge base for the connections we commonly use is very limited, and little is being done to provide more effective ways to make connections. Automation and robotics at manufacturing plants and on the construction site will only become a reality with effective connection methods. It should be noted that connections are critical to all segments of construction including distribtuion services such as electrical heating, air conditioning, plumbing, and the structure.

More attention must be given to failureproof connections techniques. Higher quality can be achieved with techniques that recognize human errors and corrects for them. Expert systems can contribute to this as well as provide a more effective means of monitoring construction quality.

There is a need to improve technology transfer among research and teaching programs, industry and government. We need to do research here in the U.S. and develop effective technology transfer programs to put the research into practice. Furthermore, research and development at the universities is the primary means we have of educating the engineers needed

to develop and implement new technology in the construction industry. We must be as dedicated to that goal as our Japanese friends are.

If our nation is to meet the challenges confronting us from abroad and diminish the waste of resources by providing more reliable structural systems, research and development and technology transfer must be carried out at our ATLSS Center and at other laboratories and universities in the United States. These issues are important to each of us. We cannot allow our knowledge base to stagnate.

All of us have a responsibility to see that our nation is able to meet the challenges I've described.

Dr. John W. Fisher
Professor of Civil Engineering
Director, ATLSS Engineering Research Center
Fritz Engineering Laboratory
Lehigh University

Dr. John W. Fisher, Professor of Civil Engineering at Lehigh University since 1969, was named Associate Director of Fritz Engineering Laboratory in 1971 and was Acting Co-Chairman of the Department of Civil Engineering from 1984 to 1985. In 1986 he became Director of the NSF Engineering Research Center on Advanced Technology for Large Structural Systems. Before joining the Lehigh staff, he was Assistant Bridge Research Engineer with the National Academy of Sciences at AASHO Road Test. In 1956 he received the Bachelor of Science degree in Civil Engineering and received his Master of Science and Doctor of Philosophy degrees from Lehigh University in 1958 and 1964, respectively.

A structural engineer, he is a specialist in structural connections, the fatigue and fracture resistance of riveted, bolted and welded structures and the behavior and design of composite steel-concrete members and has been engaged in some sixty research projects in these areas since 1961. He is involved with committees of ASCE, TRB, AISC, NSF, AREA, and the Research Council on Riveted and Bolted Structural Joints in these areas of expertise.

Fatigue and Fracture in Steel Bridges; Case Studies, published in 1984, and the 2nd Edition of Guide to Design Criteria for Bolted and Riveted Joints published in 1984 and 1987, respectively, by John Wiley. He has authored 150 publications for various technical journals and contributed to three other books.

In 1982 he was a Visiting Professor at the Swiss Federal Institute of Technology; in 1984, the Institution of Engineers' Civil College Eminent Overseas Speaker in Australia; and Senior Visiting Scholar to the People's Republic of China in 1985. He has received awards from ASCE, PSPE, AWS, AISC, and Lehigh University.

In the spring of 1986 he was elected a member of the National Academy of Engineering, and he was chosen by Engineering News Record as 1987 Construction Man of the Year, the first member of the academic community to receive this award.

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Mr. WALGREN. Thank you, Dr. Fisher.

Well, you all generally are feeling that something focused has to come from the federal government, and we seem to have a great deal of time—great deal of trouble getting anything focused from the federal government. In fact, the Building Technology Center has been one that has been not appreciated, certainly these last seven years, in the administration's review of the Department of Commerce and ultimately the Bureau of Standards.

The question then is, is—can there be agreement on a specific agenda for a federal research program?

Dr. Wright, you emphasize this concept of open systems, and it's hard as someone on the outside to quite appreciate how that or what kinds of work that's done there, and how directly it would be appreciated by the construction industry.

Would the other panelists agree that the NBS program is focused on the things that you would give priority to?

Dr. Fisher.

Dr. FISHER. Yes. I think—I personally do not have any major difficulties with some of the thrust of the NBS program. I think though that we must recognize that there's a role for both the government laboratories and universities as well as industry labs.

And I think the—in the discussions that I've had with many industry individuals it would seem to me that nobody from industry seems willing to carry the ball. And that many have indicated to me that perhaps there should be a fee put on construction permits much as some states have implemented fees, for example, on environmental studies.

So, I think the thrust—all of us probably have the same visions for the next century. And I think in order to provide for a mechanism to do something other than this focus research, which is almost all that is being done today, we're not, as Dr. Moavenzadeh said, we're not doing anything significant across the nation in exploratory work. And that's what we're going to need, as we need the challenges of the next century.

Mr. WALGREN. Would the others like to comment on how we can agree on an agenda, on a research agenda?

Dr. MOAVENZADEH. I think at present time the issue of agenda is more important than who has to do that research, because I believe at the present time within the U.S. government agencies, as the Bureau of Standards' effort indicates, academic institutions, industry of research organizations, there is enough capability to do the basic research in this area. The question is, that there is not enough funding or interest at present time directed toward this particular issue.

All the research that has come to the construction has come by what we call invasion of construction market. The work has been done in another industry. They have looked at the construction as a potential market, since it is very large, and then they have tried to apply and adapt that activity to the construction market.

This so far has been fruitful and has been helpful to the construction industry, but has not created a research environment in the construction with a specific set of goals and objectives to improve the competitiveness or the productivity of the construction.

So we basically have been in a passive mode of research. Wait to see what the others will develop for us before we use it rather than establishing a research agenda, a research set of goals and objectives for that research, and then finding out how much it will cost and who has to do it and how long it will take and what we are going to get out of it. That type of mission oriented research with a specific set of tasks and outcomes; and with a specific set of agenda has not been developed for the construction industry.

Mr. WALGREN. Dr. Wright, how do we decide what it is we're going to look at in the Bureau of Standards? How did you come to the open systems focus?

Dr. WRIGHT. The focus on open systems is very consistent with the traditional role of the Bureau of Standards in providing performance prediction and measure and technologies for U.S. industries. And it's by this ability for buyer and seller to communicate in terms of the qualities they want in product or services that we have strong private sector innovation and a rapidly developing technology in economy.

Let me comment just a bit on the agenda question that you asked earlier, Mr. Chairman, as well.

Mr. WALGREN. Just to be certain then, the research that's going on there really is not driven by the needs of the industry at that point, but rather by the traditional role of the Bureau of Standards, and I would gather, some of the other work in other parts of the Bureau of Standards that's going on with computer capabilities and the like.

Dr. LYONS. Yes and no. I think that the opportunity to do something in interface standards in the construction industry does address a need of the industry. It also happens to be concurrent with the current NBS role.

So, I think that it was a sensible thing for us to begin with that standards interface question or the open system question.

I would like to add another comment. I agree with the thought that, first, we ought to agree on the agenda before we worry about who does it. However, I think that agreeing on the agenda will be a lot easier than figuring out how to get American construction companies to begin to do some advance development, if I may call it that. And I don't think any amount of government research per se is going to do us any good if there is no one to pick up on it.

And my greatest concern today would be that American construction firms don't do any advance development, and don't even seem to have a very positive view of it.

It would seem to me that the only hope we have is that the increasing competition in this country in the construction industry from offshore firms may stimulate a change in thinking. I think that's the big problem.

Mr. WALGREN. Tell me a little bit about what that competition looks like. Dr. Fisher mentioned the welding process and the modular assemblies, but can you give what they are doing abroad a little bit more life and flesh and context.

Dr. LYONS. Well, Mr. Chairman, I meant something else. I meant the offshore companies are taking business in this country. That's what I meant by competition. I think people will begin to worry about advanced development when they start losing market share,

and we believe that's happening. Maybe Dr. Wright can amplify on that.

Mr. WALGREN. But are there visible differences in techniques so that you can look right at what their advantage is.

Dr. LYONS. Do you want to talk to that?

Dr. WRIGHT. Yes. We see in the Japanese laboratories a great deal of work in developing such things as the slurry shield tunneling method, much more efficient in certain types of soils, and that is now winning jobs here in the United States.

We see in the very large shaking tables that the Japanese have available and that we don't. They are developing and verifying nuclear reactor systems that will give them substantial benefit in third world countries, in competition for providing these facilities.

We see work on developing base isolation systems for earthquake resistance of buildings, and their verification on facilities that we don't have available here in the United States.

These things are being done jointly by the Japanese government laboratories, by the universities in Japan, and by very substantial developmental investments on the part of the Japanese construction firms.

Just to go back to a couple of the earlier questions, I appreciate it very much, Mr. Chairman, your follow-up on our agenda. It needs to be driven in the construction industry. We work with standards, developing organizations from the steel industry, from the concrete industry, from the timber industry, masonry industry. We work with organizations such as the National Institute of Building Sciences to understand the most pressing needs that the construction industry has for improved measurement technologies. And that is where we focus our program.

Mr. WALGREN. And how big a program are we conducting there now?

Dr. WRIGHT. Our program at the present time is about $3 and a half million base funding with about twice that much coming from other federal agencies in the private sector. And, of course, it's only that base funding with which we can look ahead at problems five or six years down the line and get ready for those.

The work with the other federal agencies is dealing with their present day needs for improved technologies.

I would also comment on the research agenda that we need not only a problem focused research agenda, we very much need this. But we also need to be encouraging innovative research on the part of investigators and universities and the private sector and in government organizations to look ahead five, 10, and sometimes 20 years to provide the knowledge that will be vital in the future.

We can't get by with simply a problem focused research agenda. But we don't have that now and we do need it.

Mr. WALGREN. Are there other examples of competitive edge that have come to the mind of other members of the panel?

Dr. HAVILAND. Let me make a comment, Mr. Chairman, on the question of agenda. I think the mechanisms are there for the private sector and the public sector to work together to establish such an agenda. Here in Washington we have organizations like the National Institute of Building Sciences that you'll hear from this morning; the Building Research Board at the Academies, our own

committee had on it representatives of organized labor contractors and so on.

And I would point out that there are a growing number, maybe embryonic would be a—I hate to describe Dr. Fisher's operation as embryonic—a growing number of operations in the country that involve public and private participation together. The Engineering Research Centers program at NSF, which is one I know you know well, is really built on this concept by providing some public stimulus, we have an opportunity to involve the public and the private sector to work together to establish agenda. The ERC at Lehigh is the only one in the construction area.

There is a Construction Industry Institute at the University of Texas which has a fair amount of private participation, but they, too, are limited and that the basic—the basic amount of money to fuel the operation is so low that agenda setting in some cases becomes really a moot exercise. But there are examples.

Mr. WALGREN. Dr. Fisher.

Dr. FISHER. Yes. I would like to point out that we should recognize that the major Japanese effort has not been long-term. The International Construction Industry Committee of the National Research Council, which I chair, had a dialogue a couple of months ago with five of the major Japanese firms operating in the United States. And they've only been investing this one percent for their gross over about the past five or six years.

In the mid-'70s after the oil shock apparently a strategy was developed in Japan of which—and just how that was developed I'm not sure at this point. But nonetheless it has resulted in the Japanese starting at about 1980, '81 building to that level.

And I think if we look at the other industries that have been impacted by our offshore competitors we must recognize the amount of effort that they have been putting into research has not been so long range, and hence—but the longer that we wait the more adverse impact that has to have on our nation.

And so—I think we do see other Japanese efforts. I had mentioned and what has been mentioned is the one on tunneling. I think the die casting technology for small power tools is one in which the Japanese have a substantial technological edge. And there are others. The smart crane technologies, and much of the robotics work. Maybe it is not fully implementable at this time, but with the amounts of resources they are devoting at this level, at this time versus the amount that we are, it has to have an adverse impact on our nation in the long run.

Mr. WALGREN. Well, I want to recognize now the ranking minority member, Mr. Boehlert from New York and ask him if he wouldn't please take the Chair, and he has an opening statement. As you know, Mr. Boehlert has maintained an interest in this area in particular, and we appreciate his focusing on this for the subcommittee because it's an area that we feel is very important.

Mr. BOEHLERT [presiding]. Thank you, Mr. Chairman. I first of all would like to explain the lack of participation by some of my colleagues on the Republican side. I've just come as Mr. Ritter from a Republican Conference where we were electing important leaders for policy positions, and it was mandatory that we all be there. It's

not for any lack of interest because this is an area and subject matter that I have a deep interest in.

And, Dr. Fisher, it's nice to see you again. It's nice to see all my friends on the panel.

I do have an opening statement that I am going to read for the record, and then I want to zero in on some specific areas.

This morning's hearing comes at a pivotal point in the history of our nation's construction industry. American construction firms and their suppliers are facing increasing competition, both at home and abroad, while new technologies hold out the hope of making buildings cheaper, safer, and more efficient.

Much is at stake. The construction industry is in many ways the keystone of our entire economy. The industry itself accounts for about eight percent of our GNP, and the quality of its products help determine the productivity and the profitability of the rest of American business. Our very quality of life is dependent upon construction firms; after all, they build our homes, our schools, our highways and our churches.

And as we've seen too often recently, the quality of construction can be a matter of life and death. The collapse of the New York State thruway bridge in my Congressional District demonstrated vividly and tragically, that we cannot take construction quality for granted.

A few years ago it seemed like every politician in America was touting the need to rebuild our infrastructure. The headlines have disappeared, but the problem has not.

The cure for our construction problems is as obvious as it is ignored. The cure is more research.

Now, I don't mean to suggest that the current inadequate level of research is the sole reason the construction industry appears to be in the doldrums. And all the research in the world won't make a difference if the results are not applied. But research is needed to automate construction, to improve energy efficiency, to develop better bridge designs, and inspection methods, and to cut construction costs.

Other nations understand this. They concentrate more on research than we do, and they watch to see if we'll catch on.

Shortly after I organized a National Conference on construction in my Congressional District last June the Japanese Embassy's const. uction attache came to see me, just to chat about where I saw American construction heading. I doubt if our Embassy in Japan is monitoring this issue with equal diligence.

At today's hearing we should be able to get a better sense of exactly what enhanced research could do for American construction. The testimony will expand upon the excellent National Academy of Science's study of this issue, which concluded that the federal government should be spending more on construction research. I most certainly and emphatically agree.

Government, industry and universities are going to have to work together to ensure the long-term health of the construction industry, and in turn, of the American economy.

This hearing, along with our committee's continuing efforts to build up the National Science Foundation and the National Bureau of Standards, should help set us on the proper course.

Incidentally, the authorization bill for the National Science Foundation was on the Floor yesterday and, as you know, it's the first leg in a five-year program for a 100 percent increase in NSF, and I am pleased to report that we passed that bill by a vote of 407 to 3. Now we are going to work on those three people for the next time.

Today, in 20 minutes, the National Bureau of Standards bill will be on the Floor, and as you also know, there is a recommended increase in the budget. Apparently we have got their attention downtown to begin to appreciate the underappreciated NBS, and I fully expect equal enthusiasm to be demonstrated by my colleagues in giving that agency the money it needs to do its job.

Now——

Mr. RITTER. Mr. Chairman, could you yield for just a moment?

Mr. BOEHLERT. I'll be glad to yield.

Mr. RITTER. Since I faced the same difficulty you had, we had our leadership elections this morning, but I wanted to welcome our very distinguished panel, and in particular my good friend and my constituent, Dr. John Fisher from Bethlehem, Pennsylvania, and I am very proud of the achievements of that constituent. John serves in the National Academy of Engineering. He heads up the Research Center, Engineering Research Center, quite relevant to the topic at hand today, and I might point out in addition, following up on my colleague from New York's remarks, I think I want to associate myself with those remarks, and then say that we have this problem of fragmentation of industries across the length and breadth of the American economy, and we have seen the inability to bring forth critical mass research efforts and funding efforts for these industries.

Now construction is not alone. Homebuilding might be another phase of construction, but I think we are also talking about the broadcasting industry. I spoke at a national convention of broadcasters, and the length and breadth of this auditorium was immense and there was tremendous resources there, but they too did not have a focused effort, and were just trying to get going with a focused effort in research and development.

Cable television is another area of lots of wealth and length and breadth of an industry, but no focused efforts in research.

We have seen what's going on in the semiconductor industry with the entire range of electronics and computer and some electric companies getting together to collaborate and provide central focus to industrywide research. So I think the subject of the hearings today, Mr. Ranking Member, are very relevant, and I commend you and the Chairman for your leadership in this area.

Mr. BOEHLERT. I thank my colleague from Pennsylvania.

Dr. Wright, does the Center for Building Technology conduct any research that would relate to the questions that were raised by the bridge collapse over the Schoharie Creek?

Dr. WRIGHT. The Center for Building Technology had a program on geotechnical and foundation engineering that was originated about 10 years ago. However, with the severe constraints on our budget and the cuts that we have endured over the past few years, this program had to be terminated two years ago, so that at this time we have no work underway on geotechnical or foundation en-

gineering that seems to be the key issue associated with the tragic bridge collapse in your district.

Mr. BOEHLERT. Of course, you know there were some efforts underway to terminate CBT.

Dr. WRIGHT. Yes.

Mr. BOEHLERT. And I want you to know—well, you know already that this subcommittee is very strong in support of it, and thanks to our effort, CBT is alive and well.

Are you involved in any way, shape or manner in the investigation of that incident?

Dr. WRIGHT. In the investigation of the bridge collapse? No, we are not involved.

Mr. BOEHLERT. Why not? Anybody talk to you about it?

Dr. WRIGHT. We were—we have talked with staff of the Federal Highway Administration about the problem as one of general common interest, but it was not one that they called upon us for assistance in, and as I say, our abilities to give assistance in this area have been very severely restricted by staff losses that we have suffered the past couple of years.

Mr. BOEHLERT. Has CBT done standards work on bridges in the past?

Dr. WRIGHT. CBT has done standards work on foundations for structures, which would include bridges, and up till recently, we chaired the Committee of the American Society of Civil Engineers for developing nationally applicable foundation standards that don't currently exist.

We do a good deal of standards work in areas such as safe construction technologies, wind loadings on structures, and much of this is very pertinent to the problems of bridge engineering.

However, the major federal responsibility for bridge engineering research is with the Federal Highway Administration.

Mr. BOEHLERT. Do you think existing inspection programs are adequate?

Let me preface while you're thinking about it a little bit, Senator Moynihan had a hearing up in Amsterdam after the collapse of the bridge and tragedy, and he was gracious enough to invite me to participate, and I welcomed that opportunity, because I am determined to follow through on it, and not just a public relations charade, one hearing in the high school where all the cameras are, but to follow through long range. And the Commissioner of Transportation for the State of New York and the top man for the Throughway Authority, Chairman, took great pride in telling us that immediately after that tragic accident, they had inspected all 167 bridges on the New York State Throughway, and found none of them to be at high risk. And my question was, had you inspected that bridge the day before the tragedy, the bridge over the Schoharie Creek, what would have been your finding? They said not at high risk. That gives me little comfort.

Now can you address that question, do you think existing inspection programs for bridges are adequate?

Dr. WRIGHT. There are the inspection programs themselves, and there is the technology base that lies behind the programs.

Mr. BOEHLERT. Let's take them one at a time. Is the technology base adequate? Is it properly being applied?

Dr. WRIGHT. The technology base is not adequate for really efficient and thorough inspection in a cost-effective way. A great deal needs to be done to develop nondestructive inspection techniques that let us find hidden flaws——

Mr. BOEHLERT. Where do we go for that?

Dr. WRIGHT. That's one of the areas in which our laboratory can help.

Mr. BOEHLERT. Is there enough money in this year's budget, recommended budget, to do something?

Dr. WRIGHT. We are working, for instance, on flaw detection in concrete as one of the high priority areas, and we have enough funding to do some very useful work in that area.

Mr. BOEHLERT. Well, I'm going to follow through on that. Now how about the inspection programs themselves, using existing technology? Do you think they are adequate?

Dr. WRIGHT. I don't really feel that I have had the direct involvement in those programs that would allow me to speak authoritatively in response to that question.

Dr. FISHER. Mr. Boehlert?

Mr. BOEHLERT. Dr. Fisher, I am coming to you next, because I have something for you, but I'd like to——

Dr. Fisher. Well, I'd like to make some comments on that, since I have worked with bridges for more than 20 years, and have written extensively on inspection of bridges, as well as some of the difficulties of different types of bridges; more related to cracking problems.

I think there is not available technologies that we need in the areas of sensing, and as we look to the next century, I think we should be looking to develop and use some modern technologies where we do not have disposable sensors that could be permanently installed on structures to monitor them, to tell us what's going on. And I think we need to get on with that. We have work in our own Atlas Center directed to some of that, in the area of corrosion detection, and we expect to continue to do some work in crack detection.

So I think there is a need to look into exploratory technologies, and that gets us back to this same issue that keeps coming up of focus versus exploratory. We in general in this nation primarily look at focus problem areas, and that's where the concern is, and that's where the immediate focus is, and we don't pay any attention to new technologies that we should be trying to apply.

Now on the issue of whether these inspections are adequate, I think there are some major problems with the way inspections are done, and in part I think that we are making a mistake applying equal weight, as we do today, and having a mandatory bi-yearly or every two-year inspection period. I think that is wasting a lot of resources, and I personally would prefer to see resources more focused where we can, using sound engineering judgments and calculations and identify areas and put more focus on those kind of areas for inspection, than just going out and because of the laws, have every bridge inspected the same. That's leading, I think, in my opinion, to wasted resources, and it is not applying the resources to critical areas that should be inspected.

Mr. BOEHLERT. I can appreciate that, but the thing that bothers me, using the existing methods and the technology as it is applied, you could inspect these bridges every half hour and you still wouldn't uncover what happened in that tragic accident on the Schoharie Creek Bridge. Are you familiar with that particular one, Dr. Fisher?

Dr. FISHER. Yes, I am somewhat familiar with that, yes.

Mr. BOEHLERT. Raise your right hand. You are now assigned as an unpaid official consultant to me. Do you take an oath that you'll give me the best advice you can forevermore? I mean I am really determined to follow that on it, because my worry is this, that you have a tragedy like that, 10 lives are lost, and you have the big hearings, and you have the big splash by the media, and then too many people go back to business as usual. I am absolutely determined to follow through on this. I want to know if the technology is there. If it's not, I want to know who needs the money. If Dr. Wright needs more money, he's going to get it from me, and I will do my level best to convince my colleagues that they should support it.

How many more bridges do you think might—I mean this is a tough question—the same type of basic flaw that created the problem at the Schoharie Creek Bridge?

Dr. FISHER. Well, I am not sure that we know completely all of the reasons for the collapse of the Schoharie Creek Bridge. It does appear that the underwashing of the foundation is certainly one of the major suspects, and therefore I would not want to make any comments that would presuppose that all the facts are in. I think that would be dangerous. There might be other contributing factors. But I think there is a need for new technologies. I mean surely there are some technologies that have not been developed that would permit inspection or sensing devices to permit, if they were installed, knowledge of washout.

But this again goes back to the issue of looking at conditions that might be more suspectible than others, such as the Schoharie Creek, which apparently did not have pilings under the piers. Those probably can be identified and some more focused inspection applied to structures of comparable exposure in the environment.

Mr. BOEHLERT. I don't mean to be an alarmist, but I have to believe there are a lot of other bridges around that use that same basic technology and the same circumstances exist.

Mr. FISHER. Well, I can agree with that. There's no question that there are many others that are likely to be at risk, and certainly loss of foundations is one of the major reasons for bridge failures each and every year that passes.

Mr. BOEHLERT. It's not fair for me to monopolize, but I'm taking advantage of sitting in this chair. Dr. Fisher, could I ask you as a personal favor in your new capacity as my consultant to give some thought to this and to prepare a memo for me at your convenience—and I know you are very busy, but it's important to me, and I do want to follow through, and of course with my friends from the Bureau, the Center for Building Technology, they are going to be hearing a lot more from me.

Does anyone else have any further comment on this particular aspect of my questioning? How about Mr. Ritter? Do you have any questions you'd like to ask?

Mr. RITTER. Not at this time.

Mr. BOEHLERT. All right. I'd like to thank the panel very much, and you will all be hearing some more from If anybody on the panel has any further thoughts on this particular aspect of my questioning, please share them with me, and Dr. Fisher, I appreciate your willingness to help.

Thank you very much.

The next panel will consist of Mr. John Miller, who is Chairman, Research Committee, National Association of Home Builders; Mr. Harold Adams, from The American Institute of Architects; Mr. Rene Henry, President and CEO of the National Institute of Building Sciences; and Kenneth A. Roe, who is Chairman of Burns and Roe. And as the panelists assemble, we will have some name identification tags up there for you momentarily.

Let me also explain we are playing musical chairs, and shortly I will be vacating this chair and I will turn it over to Mr. Valentine of North Carolina. We have the unusual predicament today—let's see, Mr. Roe Okay, fine, we've gone one up—the unusual predicament today of in five minutes the House is going into session, and the National Bureau of Standards authorization is the first item up on the Floor, and the Chairman and myself as the Vice Chairman of the committee will be managing that bill, and we have to be there. I apologize for that, because I know we have got some outstanding panelists here who have a lot to contribute, but I want to assure you, this is a committee that follows through, we read testimony; we are not reluctant to call up and ask questions and that sort of thing. So you will be hearing some more from us.

If you will, Mr. Miller, why don't we take the panelists in the order called. Our first panelist, John Miller, Chairman of the Research Committee of the National Association of Home Builders. Welcome to the committee.

STATEMENTS OF JOHN MILLER, CHAIRMAN, RESEARCH COMMITTEE, NATIONAL ASSOCIATION OF HOME BUILDERS; RENE A. HENRY, PRESIDENT AND CEO, NATIONAL INSTITUTE OF BUILDING SCIENCES; HAROLD L. ADAMS, FAIA, THE AMERICAN INSTITUTE OF ARCHITECTS; AND KENNETH A. ROE, CHAIRMAN, BURNS AND ROE

Mr. MILLER. Thank you for the invitation.

Mr. BOEHLERT. Would you pull the microphone closer and switch it on. We want to make sure we hear everything you have to say.

Mr. MILLER. Thank you.

First I'd like to say, it is a pleasure to be here and I appreciate this opportunity to be able to present our views.

I think we're in a position now to do some things, so let me tell you a little bit about myself. I'm a home builder, primarily from Tucson, Arizona. My dad was a builder. I grew up in the trenches, so I know what it takes to make things happen out there in the field.

I've been President of the Southern Arizona Home Builders in Tucson, Arizona. I'm now the Research Committee Chairman for the National Association of Home Builders.

I've also been Chairman of the Arizona Solar Energy Commission. And I'm involved in a building project in Arizona called Biosphere II which is to enable us to colonize space.

So, my interest goes a little further than just building houses, although I cannot emphasize how important it is to start looking at innovation and technology transfer into the home building business, so that affordable housing can be a reality again.

I think the opportunity is now here to take advantage of the state of the art technology and to encourage new development. Due to the competitiveness of the marketplace, and also, the foreign entry into the market, I see a returning interest adding to that equation, and that interest is in quality; quality of life, quality of product, and quality of craftsmanship.

People are willing to pay more for something that's a little better. We see that example in the automobile industry, and we see the innovation happening. Quality nurtures innovation and creativity.

The National Association of Home Builders Research Committee is now in the process of setting the research agenda for housing. In response to some of their earlier comments presented today, we are in fact addressing that issue right now, so that we can truly be on the cutting edge of innovation in the housing industry. These innovations can carry over into all forms of construction.

We voted at our spring board meeting to institute a study on technology assessment. That's the start to identify how we start solving problems, how we start eliminating the barriers such as impact fees, and how we start introducing new technology and things that can happen.

One of the best examples we've got is the National Research Center, a division of NAHB which has now come upon a new program after many years of study in work called the Smart House. The smart house is literally going to change the way we live in using housing, it's a totally new wiring system that's going to offer opportunities to use houses and improve the quality of life, security, early warning systems. Older people are going to be able to stay in their houses longer. And we've been able to do that because some of the rules were changed.

The broad base of our association enables us to bring together people who had not previously worked together before because of the competition factor. We have approximately 147,000 members now, and the clout we have with the manufacturers enables us to bring them together on a joint project to develop something that has never been done before.

In a year or two we're going to have a project on-line that enables us to truly sell a smart house; a house with intelligence.

NAHB by its very nature of representing the broad section of the entire construction industry which not only includes builders, subcontractors, land developers, lawyers, bankers, and real estate people. It encompasses almost every trade or every area of expertise that one can think about.

So, we can be the facilitator of information, education, and technology transfer to the people in the trenches. Now, that's a critical thing.

We can all sit here and talk for hours and days and weeks and months and not get anything done. We've got to get that information out to the people who that do the work. We have to make the people in the trenches comfortable with the new technology.

NAHB represents the total system. The example I gave of not only the builders but all those other people enables us to bring them together. What we can do with government is encourage centers of excellence at universities, to cooperate with NAHB, to educate and to bring that technology transfer to the people that do the work.

We could encourage states in their codes to eliminate the barriers to new technologies.

And finally, we can change the mind-set that "quality" means slow. I was fortunate to grow up working with craftsmen who were not only the best, but they were the fastest. Now that's a difference. For a long time we were taught that to do a quality job you had to be slow. It's not true.

I really feel fortunate that I was able to experience that because I worked with painters and carpenters, plumbers and electricians who were the best in their craft. They were also the fastest. That gets to the point of productivity and affordability. We can deliver a quality product in an efficient manner, so that it can be affordable.

How are we going to do that? By education and example. The Job Corps is a good place to start. NAHB sponsorship of the Job Corps has turned a loss, a loss of ability of young kids into a gain, a gain for this country and we're producing craftsmen who earn money and pay taxes.

Together the public and the private sector can collaborate to do more than just redefine problems. We can provide solutions.

Thank you.

Mr. VALENTINE [presiding]. Thank you very much, Mr. Miller.

Mr. Roe, we would be happy to hear from you at this time, and your prepared statement will be made a part of the record in toto, and you proceed in any way that you deem appropriate. We're glad to have you here, sir.

Mr. ROE. Thank you very much.

My name is Kenneth Roe, I'm Chairman and Chief Executive Officer of Burns and Roe Enterprises. And as you can see I'm a practitioner in this field.

For 55 years my company has been a major provider of engineering, design and construction management services in the United States and overseas. We are pleased to have this opportunity to appear before this committee charged with looking into research and competitiveness in the construction industry.

Let me preface my remarks by concession. I may not be the expert on the current state of construction market outside of the US, because virtually all of our company's current overseas work involves either engineering and design and special consulting where construction is a necessary project completion operation.

At the same time I am familiar with many of the problems that construction industry has faced overseas. Over the years Burns and

Roe has been involved in projects in West Germany, Switzerland, Norway, Spain, England, Mexico, Portugal, Venezuela, Belize, Bermuda, Cuba, Zanibar, Argentina, Australia, Guam, Philippines, Indonesia, Saudi Arabia, et cetera.

We are currently involved in various projects in Korea, Japan, Taiwan, China, Thailand, Malaysia, Hong Kong, Diego Garcia, Italy, and the Dominican Republic.

Today I intend to emphasize two of the many points relative to the subject of these hearings. Both points involve government support and assistance.

The first point concerns overseas markets that are totally closed to the U.S. construction industry or where foreign governments have set severe restrictions at American construction firms find it almost impossible to compete. Japan is a good example of this.

At this time Japanese investment in the U.S. construction is extensive and growing every day. Yet the Japanese government makes it virtually impossible for the U.S. construction firms to build anything in Japan.

Let me make clear that what I'm calling for is not, and I emphasize not, trade restrictions. I oppose tariffs or trade barriers of virtually any kind, particularly for the construction industry.

The support we need from the U.S. government is an effort to open up these foreign markets to U.S. firms so they can be competitive. In our business we know, you can't win it if you can't bid it.

Anything this committee can do to help open foreign markets will increase U.S. construction industries opportunity and ability to be competitive.

The second point I would make is with technology. Burns and Roe current and often past success on overseas construction projects has been primarily due to our involvement in joint ventures or consortia. For example, we are currently doing engineering design work on a barge mounted powerplant for Thailand; a project which we and our Korean partners won by underbidding the Japanese.

We were able to win because the Korean wage rate is lower than the Japanese wage rate. And, of course, because of our experience in designing innovative powerplants gained from over 50 years of technical background.

We must face the fact that the U.S. wage rates are and will remain high. Under these circumstances the only way to meet competition is to improve productivity through innovation, its implementation, and R&D.

We must set about a rapid development of our own new technologies. I say rapid because we are not merely behind, but in my opinion we are falling further behind every day.

Despite the situation advances in this country's construction technology have been quite limited. Many of the reasons for these limited advances in the construction technology can be laid to the doors of the construction industry itself. It is a fragmented industry hampered by inertia, and with little technological innovation or transfer.

Our industry has additional problems of situation awareness and internal communication. In some instances, however, the government, state and local as well as national, is a culprit.

Building codes often hamper technological advancement. Government regulations, particularly some of those promulgated by federal agencies actually often deter technological innovation.

A review should also be made of any other regulations dictated by governmental or tax policy that disincentizes foreign construction activities by American firms.

Comparison of support given by foreign governments could highlight areas where our competitive position could be improved. Action should be taken to correct all categories of problems of this type.

Support of R&D, no matter how funded provides a technological edge for the United States. The new processes, the new products developed provide additional opportunities for the U.S. construction industry, both here and abroad.

Broad R&D support should be a major effort, not only of our government, but all segments of our economy. More specifically, the government should foster and support more research in development activity in the construction field itself.

There are at least 180 organizations in this country with capability to do construction R&D. They run the gamut from federal government agencies and universities to non-profit groups, professional trade organizations, and private companies.

As one example I would specifically refer to this committee to the Construction Industry Institution which has sponsored a great deal by private industry and run by the University of Texas as a type of, but not the only organization, deserving a financial support from the government.

Let me conclude by commending this committee for its efforts to assist the construction industry and its attempts to develop new technology and find new markets. The Japanese have taught us a valuable lesson in how government can work hand-in-hand with industry, sometimes fairly and sometimes not fairly, in opening new markets for Japanese industry. We need some of the same kind of support, government working together with industry in an integrated and cooperative effort in every area of foreign trade. In the construction industry, assistance in the opening of foreign markets, and encouragement of more construction R&D is particularly needed at this time.

Burns and Roe, for one, hopes that this committee is successful in its effort to achieve these goals.

Thank you.

[The prepared statement of Mr. Kenneth A. Roe follows:]

Mr. Chairman and Members of the Subcommittee, my name is Kenneth A. Roe. I am Chairman and Chief Executive Officer of Burns and Roe Enterprises. For 55 years my company has been a major provider of engineering, design and construction management services in the United States and overseas. I am a practitioner in construction and so my comments may be a bit different from those of my colleagues. We are pleased to have this opportunity to appear before this committee charged with looking into research and competitiveness in the construction industry.

I am delighted that the Congress of the United States is taking an active interest and concern in these subjects. It is an unfortunate circumstance, but a fact nonetheless, that our construction industry is considerably less progressive than some other major industries in developing and utilizing advances in technology. There are reasons for this, of course, but the effect is clear; we are failing to seize opportunities to increase our productivity levels and decrease our costs of construction. And the result of that is not simply clear, it is also compelling. We are tending toward becoming less and less competitive in world markets, and we are becoming less competitive, compared to firms from other countries, even here at home. Top foreign contractors increased the dollar value of construction contracts captured in the United States from about $2.9 billion in 1980 to an impressive $7.3 billion in 1985, two and one-half times their market penetration in 1980. That is a remarkable - and frightening - average increase of 20% each year over the five-year period. Your interest and concern in these twin topics of research and competitiveness in our construction industry come not a moment too soon.

Let me preface my statement with a concession: I may not be the expert on the current state of the construction market outside the U.S. Virtually all our company's current overseas activity involves either engineering and design, or special consulting assignments, where construction is necessary for project completion.

However, at the same time I am familiar with many of the problems the construction industry has faced overseas. Over the years, Burns and Roe has been involved in projects in West Germany, Switzerland, Norway, Spain, England, Mexico, Portugal, Venezuela, Belize, Bermuda, Cuba, Zanzibar, Nigeria, Argentina, Brazil, Australia, Guam, The Philippines, Indonesia, Saudi Arabia, Bahrain, Egypt, India, Jordan, Turkey and Yugoslavia. We are currently involved in various projects in Korea, Japan, Taiwan, China, Thailand, Malaysia, Hong Kong, Diego Garcia, Italy and the Dominican Republic.

Today, I intend to emphasize two of the many points relative to the subject of these hearings. Both points involve government support and assistance.

The first point concerns overseas markets that are totally closed to the U.S. construction industry, or where foreign governments have such severe restrictions that American construction firms find it is almost impossible to compete. Japan is the best example of this. At this time, Japanese investment in U.S. construction is extensive, and growing every day. Yet the Japanese government makes it virtually impossible for U.S. construction firms to build anything in Japan. The refusal of the Japanese to allow American firms to even bid on the Kansai Airport project is perhaps the best example.

Is the ability to do business in overseas markets of great importance to United States designers and builders? I'll say it is! According to statistics recently published by ENR, the weekly construction magazine formerly known as the Engineering News-Record, U.S. design firms and construction contractors earned some $24 billion in revenue in 1986 from foreign contracts. That comprises about one-sixth of our total 1986 combined design and construct revenue, a substantial proportion. But foreign work is declining. The demand for basic industrial capacity has diminished and we're facing increasingly stiff competition overseas from foreign competitors. In 1981 and 1982 our nation's top construction contractors counted about a third of their total revenues from major contracts awarded overseas. By 1986 that proportion had

dropped steadily to about a fifth. In 1980, a good year, U.S. firms captured nearly 45% of the dollar value of contracts awarded to major international contractors. In 1984, that market share was about 38%; it was less than 35% in 1985.

Compare those facts with data on how we are competing with foreign firms here at home.

I have already cited the fact that foreign penetration of our domestic market rose from $2.9 billion in 1980 to $7.3 billion in 1985. Let's peer behind that data and see what's really happening.

Just five years ago, in 1982, foreign construction contractors numbering in the top 250 international contractors, seized a total of about $4.8 billion in new contract awards. The leading country was Germany, whose firms gained about $2.2 billion in new awards in the United States. The British were second that year, with $1.5 billion and the French were running a distant third with $0.4 billion. Trailing the top five competing foreign countries were Italy and Japan with about $0.1 billion of new awards each.

By 1985, that picture had changed dramatically. German firms obtained just over $2.0 billion of new work in the United States, a drop of about 9%. British firms were hit harder with a decrease of some 47% to $0.8 billion. Many dollars of those lost British revenues were drawn across the channel to French firms, which plunged ahead to over $1.0 billion for an increase of about 157%. Italy increased its share of the U.S. market modestly by 28% over the four years of 1982 through 1985, but the real winner was none other than Japan. Japanese construction firms, in 1980, earned essentially zero revenues from the U.S. market. In 1981 new contract awards amounted to less than $50 million. But it was a start. From about $0.1 billion in 1982, the Japanese leaped ahead to $0.4 billion in 1983 new work and almost $0.7 billion in 1984. In 1985, Japanese firms captured $1.8 billion in new construction contract awards, an incredible increase of over 1700% since 1982!

What attracted them to the American market? How were they able to penetrate it so quickly with such resounding success?

We have enjoyed a stable economy, for one thing; one magnet is the fact that foreign firms have no worries about being paid for work performed. We are non-protectionist - it's easy to set up shop here - and, comparatively, there's a lot of work. Risks are low for foreign contractors. We have a well-developed system of contract law and contractual arrangements that we follow. That makes the foreign contractor's problem of dealing with clients, suppliers and subcontractors that much easier.

How did they manage their market penetration? Over 70% of the new U.S. awards won by Japanese firms in 1985 were made by Japanese clients doing business in the United States or by Japanese-American joint ventures. By operating as joint venture developers of commercial and residential properties, Japanese and other foreign firms garnered over a billion dollars in 1985 new work. One Japanese firm has introduced tunneling technology and expertise to compete directly and successfully with American contractors. Several foreign contractors, notably the Germans and the French, have made inroads into the U.S. construction market by acquiring American firms already well established in our market. About $4.2 billion, or 58% of the $7.3 billion worth of new contracts awarded to top foreign international contractors in 1985, was captured by way of American acquisitions.

A breakdown of that $7.3 billion in 1985 provides some answers on how foreign firms penetrate our market.

How Foreign International Contractors Win U.S. Work

Market Penetration Route	$Billions
Acquisition of U.S. Firms	4.2
Real Estate Development	1.2
Japanese Company Contracts	0.6
Direct Competition: Private Sector	0.8
Direct Competition: Public Sector	0.2
Unclassified	0.3
Total	$7.3

Let me make clear that what I am calling for is not, and I emphasize NOT trade restrictions. I oppose tariffs or trade barriers of virtually any kind, particularly in the construction field. The support we need from the U.S. Government is an effort to open up these foreign markets, in the same way that our market is open to foreign firms, so U.S. firms can be competitive. In our business, we know that you can't win it if you can't bid it. Anything this Committee can do to help open foreign markets will increase the U.S. construction industry's opportunity and ability to be competitive.

A recent Asia-Pacific conference of U.S. Engineering and Contracting firms was sponsored in Bangkok in February 1987 by our Department of Commerce. Some thoughts for U.S. Government support to help improve our overseas competitiveness were aired at the conference. They included the following:

- Reexamination of current policy on taxing personal income earned overseas.

- Clarification of the Foreign Corrupt Practices Act.

- Repeal of actual or de facto laws in foreign countries that restrict U.S. firms from performing engineering and construction.

- Elimination of unfair subsidies by foreign governments to their international contractors.

The second point I would make has to do with technology.

Burns and Roe's current, and often past, success on overseas construction projects has been primarily due to our involvement in joint ventures or consortiums. For example, we are currently doing engineering and design work on

a barge-mounted power plant in Thailand, a project which we and our Korean partners won by underbidding the Japanese. We were able to win because the Korean wage rate is lower than the Japanese wage rate -- and, of course, because of Burns and Roe's expertise in designing innovative power plants which was developed by a half century of technical experience.

We must face the fact that U.S. wage rates are - and will remain - high. Under the circumstances, the only way to meet competition is to improve productivity by innovation, its implementation and R&D. We must set about a rapid development of our own new technology. I say rapid, because we're not merely behind, we're falling further behind every day. Despite this situation, advances in this country's construction technology have been quite limited.

There is another reason that we need more rapid development of technology: the impact from construction technology transfer.

Developing countries, starving for the acquisition of technology to feed the growth of their industrial capacity, employ various methods to feed their needs. They may send students to our engineering schools or they may send their engineers to work with U.S. firms for periods of time, as we have seen at Burns and Roe. Other methods include contracting with U.S. engineering firms as consultants, perhaps requiring the consultant to hire indigenous engineers and technicians, as they are available, to work in their overseas offices. Joint venture arrangements with foreign firms might be required to facilitate the transfer of technology. Whatever the method, the result is the same. There is a drain on the technology that we do possess. If we could only measure this outflow, I believe that we would discover a technology transfer deficit equally alarming as our current trade deficit and just as damaging to our economy in the long run. Since we have never been able to stem the outflow of technology over the years, I believe that we must replace it with new advances that will keep us in the forefront of global construction technology. But, at the moment, we are not pursuing research and development programs and policies that would replenish our technology transfer deficit.

Many of the reasons for this limited advance in construction technology can be laid at the doors of the construction industry itself. It is a fragmented industry, hampered by inertia, with little technological innovation or transfer. Our industry has additional problems of situation awareness and communication.

In some instances, however, the government, state and local as well as national, is the culprit. Building codes often hamper technological advancement. Government regulations, particularly some of those promulgated by Federal agencies, actually often deter technological innovation. Let me cite two examples. A few years ago, a considerable amount of money and time was spent within our A&E community to develop a standard design for nuclear power plants. One of the labels under which that attempt at innovation took place was the so-called "reference design nuclear plant," intended to decrease the time and cost required for licensing. As attractive as the idea seemed, it unfortunately languished in our bureaucracy, apparently squelched by our regulatory process. A current example seems to point the finger at common building codes, and the system under which they are promulgated, as the inhibitors of innovation. Today, the Japanese can produce manufactured homes, using automated design and manufacturing processes, to specifications established by the prospective buyer. These are not what we sometimes refer to as "modular homes." They are custom-designed with individual features selected by the owner. That technology is quite within the grasp of the U.S. construction industry but for one obstacle. Building code officials have been, as yet, reluctant to modify the codes sufficiently to permit introduction of the technology into our markets. Please understand that I am not criticizing our building code system. That, and the codes and standards established by professional societies such as the American Society of Mechanical Engineers, deserve your full support. But, we should be able to review our building codes with open minds and an inclination toward technological change when it makes sense. A review should also be made of any other regulations dictated by governmental or tax policy that disincentivises foreign construction activities by American firms. Comparison to support given by foreign governments could highlight

areas where our competitive position could be improved. Action should be taken to correct all categories of problems of this type.

Support of R&D - no matter how funded - produces a technological edge for the U.S. The new processes and new products developed provide additional opportunities for the U.S. construction industry both here and abroad. Broad R&D support shold be a major effort of not only our government but all other segments of our economy. More specifically, the government should foster and support more research and development activity in the construction field. There are at least 180 organizations in this country with the capability to do construction R&D. They run the gamut from Federal government agencies and universities to non-profit groups, professional and trade organizations, and private companies. As an example, I would specifically refer this Committee to the Construction Industry Institute which is sponsored by private industry and run by the University of Texas, as the type of but not the only organization deserving of financial support from the government.

Let me conclude by commending this Committee for its efforts to assist the construction industry in its attempts to develop new technology and to find new markets. The Japanese have taught us a valuable lesson in how government can work hand-in-hand with industry -- sometimes fairly, but not always -- in opening new markets for Japanese industry. We need some of the same kind of support -- government working together with industry in an integrated and cooperative effort in every area of foreign trade. In the construction industry, assistance in the opening of foreign markets and the encouragement of more construction R&D is particularly needed. Burns and Roe, for one, hopes that this Committee is successful in its efforts to achieve those goals.

Thank you.

Mr. VALENTINE. Thank you, sir, very much, Mr. Roe.

We welcome at this time Mr. R. A. Henry, President and Chief Executive Officer of the National Institute of Building Sciences.

Your prepared statements will appear in the record, and you may summarize or proceed any other way that you deem appropriate. We are glad to have you here, sir.

Mr. HENRY. Thank you, Mr. Valentine. It is always a pleasure to appear before this committee.

Since we last testified before this committee, our Institute formed a task force with six subcommittees looking at the foreign influence on the U.S. construction industry. Each of the six subcommittees has been meeting over the last two months. Our aim is to publish six monographs of these specific areas. Since some of my colleagues here have testified earlier on the first panel and are here participating, I won't repeat some of the statistics and data and comments that they have already made, but highlight some points I think that need to be brought out.

In the area of research and development, for example, excessive product liability awards and the readiness of our society to sue point out a serious need for tort reform. Our subcommittee in this area has said that it is driving some of our research and development offshore to avoid the "deep pocket syndrome" that's become ubiquitous here in the United States.

Other people are holding advanced products and technology off the market on advice of counsel because of the liability they would face if they did introduce the products into the marketplace.

Also, research-oriented publicly-held corporations are having an increasingly difficult time recruiting and getting competent directors to serve on the boards because of this liability issue. Something has to be done in the regulatory area. Money alone is not going to be the answer to our research and development needs.

Capital now costs more in the United States than in Asia or Europe. It takes approximately 15 years for a product from its research, development, and inception to its adoption and acceptance in the marketplace. The Europeans, we find, introduce a product almost twice as fast as we do here in the United States, because they have a single national standard system allowing for its adoption.

The tax reform legislation of last year took away a number of incentives for research and development. We need to take a look at that and find a way to encourage more research and development in the country.

Another area has been the "greenmail" of corporate takeovers. Companies have put money back into buying back their own stock rather than into productivity. As a result they have had to pare costs back. One of the first areas that has suffered has been the area of research and development areas within the companies.

Another subcommittee of the task force is looking into foreign entries into the United States, and as Dr. Lyons on the first panel alluded to, we have some figures. Of $134 billion in construction contracts awarded in 1985. $7.3 billion went to 59 foreign contractors. Now that's a 27 percent increases a over 1984, and more than double the amount in 1983. The contracting firms alone are not getting the business, but we are finding as well the architecture

and engineering and other services are also going offshore as well, so it creates a domino effect when this happens.

In 1985, Japanese firms accounted for $1.7 billion of construction contracts in the U.S. More than 70 percent of this sum was work done for their clients or joint ventures in which they were involved.

On the other hand, two German firms accounted for $1.9 billion in contracts that same year.

It is estimated that the Japanese firms did $2.5 billion in the U.S. last year. That's a 50 percent increase over 1985. And just recently it was announced that Japan's largest construction company, Shimizu, purchased a minority interest in Dillingham, one of our larger construction companies, had more than $1 billion in contracts in 1985.

At the other end of the area, we find the Finns have gone into a partnership with the Passamaquoddy Indians in Maine to build and market factory-built housing in the Northeast.

The Canadians also are dominant in the market. They have concentrated in the shopping center market here in the United States, and just five companies alone from Canada own 65 million of 3.8 billion square feet of net leasable space. That represents 17 percent of the shopping center space in the United States that's controlled by just five Canadian companies.

Another area of concern is the competition from building materials and equipment coming into this country. Imports of foreign offshore building materials are rising roughly 11 percent annually, while our exports are rising at less than 5 percent each year.

Our subcommittee also points out that 65 percent of the cement used for construction here in the United States either comes in from offshore or is controlled by offshore interests; 90 percent of the steel bolts and fasteners used in the United States are manufactured abroad, and checks by two reliable laboratories have found an unacceptably high percentage of defective product.

There is an increasing amount of counterfeit product coming into the United States. Not only are we concerned about structural steel and the fasteners I mentioned, but also some recent examples of vinyl siding which bear the code markings of evaluations and assessments of some of our model code organizations which are completely false.

I heard earlier this week at a conference in Chicago that we have electrical products and equipment coming in which are knock-offs of some popular selling high grade products here in the United States. They bear the UL label. When they are taken apart, the steel parts inside are actually tin cut up from used tin cans bearing "hecho en Mexico," and "Miller High Life" and "Coca Cola."

The United States has no agency charged with assuring the American industry and consumers that imported products and materials meet our standards. Tracing defective products to their manufacturer is very difficult when the foreign company and the products are not registered in the United States. Once they enter and pass our Customs Service, there is no way to trace them and no way to follow up and pursue them later.

Thank you, sir.

Mr. VALENTINE. Thank you very much, Mr. Henry. And Mr. Harold L. Adams, FAIA, The American Institute of Architects. We are happy to have you here and hear from you at this time. And as I have said to the other gentlemen, your prepared remarks will appear in the record in toto, and you may summarize or proceed any other way you deem appropriate. Welcome, sir.

[The prepared statement of Mr. Henry follows:]

Testimony

of

Rene A. Henry, Jr.
President and Chief Executive Officer
National Institute of Building Sciences

before the

Subcommittee on Science, Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives

June 4, 1987

Mr. Chairman and Members of the Subcommittee, I am Rene A. Henry Jr., President and Chief Executive Officer of the National Institute of Building Sciences. We at the Institute are honored to appear before you again to assist in your deliberations regarding the ability of the construction sector of the American economy to compete in the global economy and the extent of foreign influences on this sector.

One is always pleased to be called to testify here, and in this case I was especially pleased to be invited because the topics communicated to us by the Subcommittee staff are so close to the research agenda that the Institute presently is launching upon through a recently appointed Task Force of distinguished Americans.

There are few subjects of more interest to the Institute than the relative competitiveness of U.S. construction industries in a highly changing global environment. The Task Force, the names of the members of which are contained in the written testimony I have filed with the Subcommittee, has considered this complex subject and broken it down into six component parts, in all but one of which I have attempted to compare U.S. and foreign countries. The topics are research and development; technology innovation; foreign investment in American real estate; foreign entries in U.S. construction markets; competition in the areas of construction materials, components, and equipment; and productivity and quality of U.S. construction industries.

Although our research program is still at the design

phase, I hope I can give the Subcommittee information on these topics that will prove of some use.

With the Chairman's permission, I would like to read a brief abstract of the testimony I have filed.

Research and Development

The first topic on the agenda of the Institute task force is research and development, more precisely, a study of research and development in the United States' construction industries compared with those in other countries.

This is a good place to commence this testimony, for there are many knowledgeable observers who are convinced that the principal weaknesses in this important sector of our economy can be traced to the low priority assigned to research and development by our government and to the lack of financial resources of the primarily small firms that constitute this fragmented industry.

I have never seen a serious comparison in which the United States ranked economically behind New Zealand. But that is exactly where this country ranks when it comes to the fraction of total construction dollars allocated to research and development.[1]

New Zealand's expenditure amounts to 14 percent of its gross total volume of construction; ours to 12 percent. Only Australia (7 percent) and China (3 percent) rank lower than the United States. The leaders are Sweden (57 percent), Denmark (53),

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1. Source: Building Research and Development Record, Building Research and Development Advisory Board, Australian Department of Housing and Construction, 1986. The figures are for the year 1981-1982.

the United Kingdom (45), and Japan (28).

Figures arrived at by the National Research Council in its 1986 report "Construction Productivity" show that of the $1.22 billion spent on construction research and development in 1984, only $220 million, or 18 percent, came from the federal government and the rest from the private sector, with 93 percent of that from manufacturers of building products and equipment.

Federal research and development expenditures for construction in 1984 amounted to only $220 million. Only R & D in a combined group of education, training, employment and social services ranked lower.[2]

In 1984, the construction industries spent a sum equivalent to less than four-tenths of one percent of sales on R & D, making them last among major industries.[3]

These facts hamper the ability of the construction sector to come up with better ways of building. They hamper our very knowledge of the sector itself and how it performs. How critical this lack of knowledge can be was illustrated by the National Research Council's report on "Construction Productivity". The level of research and development has been such, the report said, that there are no satisfactory methods for measuring productivity

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2. Source: Schwartz, J. "Federal R&D Funding by Budget Function", the Washington Post, Dec. 10, 1985.

3. Source: "R&D Scoreboard", Business Week, July 8, 1985.

despite the importance of such measures in understanding the contributions to and effects upon the national economy of this important sector, which each year accounts for $313 billion in expenditures and more than 8 percent of the nation's employment.

There are several deterrents to construction research and development, and I believe it is important to focus upon the major ones.

First, the very nature of the entrepreneurially driven construction business itself tends to defy the kind of careful measurement upon which good research depends. In almost every project, the work is done by a temporary organization of diverse people and firms who may never have worked together, and may not work together again.

Construction is dominated by small- and medium-size firms. Because of priority allocation of revenues, research and development take a back seat to getting new business and meeting payrolls.

Second, and related, wide swings in the demand for construction services have produced in the industries an understandable caution that puts money away not for research and development but to live on during hard times and depressed economic cycles.

Third, excessively strict product liability laws and the readiness to sue that goes with them have a direct, adverse effect on research and development. We could spend my alloted

time recounting horror stories from American court rooms about liability verdicts and awards. Suffice it to say two things. One is that research-oriented, publicly held corporations are having an increasingly difficult time getting competent persons to serve as directors. The other is that in some cases, American companies are moving their research and development functions to foreign countries where less stringent liability laws apply.

Once there, they concentrate on the needs of those markets and their building systems. It takes years for the benefits of this Yankee ingenuity to find their way back to this country, and when they do, it is often because foreign companies adopt technology developed abroad by American firms and export it to the United States. This trend will continue until there is tort reform in the United States.

In other cases, where they are not relocating their research facilities, American firms are withholding new products from the market as one means of reducing their exposure to litigation and ruinous recoveries. This trend, too, will continue until some action is taken to reduce the "deep pockets" syndrome.

Fourth, capital costs more in the United States than in other countries, notably Japan, and this fact creates a disincentive to R & D investment. In construction, we have learned, it takes 15 years from inception to substantial adoption of a technological innovation. High capital costs over such a

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length of time add substantially to the costs of development.

Fifth, the incentive to invest in R & D in the construction sector is further reduced by those provisions of the new tax law that reduce tax credits available for R & D; prohibit R & D tax credits for start-up companies or for new cooperative ventures attempting to develop new products; and increase pressure on managers for quicker bottom-line results by taxing capital gains at the same rate as earnings.

Sixth, Europeans introduce new products and technologies into the marketplace about twice as fast as do Americans. There are several reasons. One is that they have a single national standard. Another is that they have government agencies staffed by experts that can move quickly to test a new product or expeditiously create testing standards for products for which no standards existed.

European governments do not regulate construction as closely as ours do. This is so, in part, because builders are required to be liable for what they build for a period of ten years, so that an incentive for quality control and new product approval and acceptance is built into the system. European countries are comfortable relying on a system of design approval and inspections imposed through the private sector.

Seventh, and finally, we at the Institute have come to realize that the passion for corporate takeovers that continues to sweep large parts of the American financial community is a

direct threat to sound investment in research and development. The evidence is clear. The enormous c sts of these takeovers and the added emphasis they place on short-term increases in profits force managers to search for places to cut costs. One of the first targets is research and development.

You will have noticed that the comparisons I have made are broad ones. That is because the research done to date is general in nature and, necessarily, has lacked the specificity required of information on which to base good public policy.

The National Institute of Building Sciences task force proposes to move beyond the general to the specific in its inquiries. It will be attempting to define research and development issues more precisely and to assess our country's strengths and weaknesses more particularly.

At this point let me illustrate a point about selectivity in research that I would commend to the members of this Subcommittee and to all our representatives in Congress when considering the complex of issues, facts, attitudes, and emotions that are what we refer to when we use the shorthand word "competitiveness."

NIBS and its task force must be selective in drafting its research agenda for two reasons. One is that there simply is not enough money to attempt to study everyone. The other reason is that not everything that is happening abroad is a "threat" or even a "challenge" to the construction sector of the U.S.

economy. We do expect to find positive influences as well that will enable us to be more competitive.

The National Association of Home Builders demonstrated how to distinguish between a perceived challenge and a real one in the field of research, development, and technological innovation. Before they began the site visits I referred to earlier, they confessed that they perceived European building systems to be technologically superior to American systems. They discovered that this was not the case when our systems are compared to those in England, France, Belgium, and the Netherlands for the simple reason that these nations favor brick and block construction. There was little that the United States, which favors a basic wood frame housing system, could learn technologically from their production processes or technologies.

On the other hand, the Scandinavian countries, particularly Sweden, make extensive use of factory produced, wood frame systems to which American builders should pay attention for two reasons. We can take advantage of Sweden's heavier investments in construction R & D, and we can get ready for increasing competition by Swedish firms in the American market in the years ahead.

The point here is that all of us who are concerned about the readiness of American industries to compete internationally must exercise some discernment, self-restraint, and common sense in analyzing the problems we face.

Technological Innovation

Another topic which the Institute's task force will address--one interdependent with the topic of research and development--offers another object lesson in the need to be selective in what one accepts to be true about the U.S. construction industries. It is the much discussed area of technological innovation in the United States and abroad.

It is true that American preeiminence in technological innovation and research and development has eroded since the end of the second World War and that this erosion has been accompanied by shifts in our industrial preeminence in some sectors.

It is true that foreign inventors received nearly half the patents granted in 1986 by the U.S. Patent and Trademark Office.

It is also true that the United States funds about half the world's research and development and is in the forefront of scientific research in almost every area of commercial interest other than construction.

Even in this sector, which I have characterized as by nature less amenable than others to research, development, and technological innovation, our problem is not fundamentally that Yankee ingenuity has died.

The Office of Technology Assessment of the United States

Congress published, in collaboration with the American Institute of Architects, a report on the deliberations of its Panel on Technical Change and the U.S. Building Construction Industry, which clues us to the real nature of the problems that need to be researched in this area.

It is not, the report assures us, that powerful technologies do not exist or are not known or understood by segments of the U.S. construction industry:

> The technologies of 'smart buildings,' computer-assisted design, and factory-construction techniques open a range of promising business opportunities. One of the most fascinating is the possibility of managing buildings as business-service companies capable of providing everything from comfortable and flexible office space to advanced communication networks and 'value-added' computer systems. The industry is clearly capable of delivering superior products where they are neeeed. But institutional problems (emphasis supplied), and an antiquated set of federal, state and local policies, may make it difficult for innovators in the industry or their potential customers to exploit the possibilities.

It is the complex of institutional problems to which the NIBS task force is turning its attention. Some of them I have already outlined for you in my discussion of research and development: the peril posed to innovation by our liability laws; the disincentives to innovation embedded in our tax laws; the cost of capital; the expense and delay of our product approval and acceptance system.

The task force will consider, as well, the time and the difficulties involved in the process through which good new ideas

go to become commercially attractive new technologies. The U.S. Department of Commerce estimates that, for most U.S. industries, this "innovation pipeline" takes between seven and ten years.

At NIBS, we estimate that the pipeline takes 10 to 15 years for construction technologies; that ten percent of the effort goes into conceiving the idea and proving its feasibility; that 90 percent goes into process and product development, including the regulatory approval process. The benefits of removing barriers to technological innovation would be dramatic. Studies by the NAHB Research Foundation suggest that a reduction of two years in the product acceptance cycle could increase return on investment by 100 percent.

The task force intends a close inspection of these various institutional problems, the result of which will be a definitive and descriptive list of the principal barriers to technological innovation that confront both U.S. and foreign manufacturers in this market.

Competition in Construction Materials, Components, and Equipment

We have been able to identify at least 10 major categories of construction materials, equipment, and components in which American producers face increasingly intense competition from their overseas competitors. "Major" in this context is defined as a category that is responsible for $100 million a year of business or more.

Latest Commerce Department data show construction material imports rising 11 percent annually and exports rising at less than half that (5 percent), due principally to the depressing effect of the strong U.S. dollar.

We have some general "seat of the pants" understanding of challenges and problems to the U.S. construction sector in this field, and I will deal with them shortly. From the standpoint of public policy research, this kind of information is insufficient, and the NIBS task force will concentrate on remedying the single greatest information deficit: accurate information about the size of the U.S. market for imported construction products and material such as steel and cement as well as for the costlier elements of building projects, the manufactured components and equipment they incorporate.

In the process, we will attempt to measure the competitive advantages and disadvantages facing U.S. producers and to identify the principal effects of offshore and onshore production.

Here are some illustrative examples of issues waiting to be defined:

1. As best we can determine, 65 percent of the cement used for construction in this country either comes in from off shore or is controlled by foreign interests, which either own and operate plants here; distribute cement they manufacture offshore through U.S. manufacturers; or sell directly to U.S. consumers.

The likely effect of the latter two means of control is the loss of domestic production and jobs.

2. The extent to which U.S. builders can rely on foreign cement production is not clear. Cement is used in virtually every construction project, and the effects on the domestic industries of the loss of U.S. control over half the supply needs to be examined.

3. What are the prospects for accelerating the annual growth in U.S. exports from 5 percent to something greater? We notice that in the U.S. steel industry, some "mini-mills" have brought their labor costs to a level that is not only a fraction of their larger U.S. competitors' but in line with costs in Japan. They are able to avail themselves of the large supply of scrap steel in this country; are manufacturing the large structural members that are in demand; and are exporting.

4. How does the American construction sector assure itself that the components it buys from foreign producers are of the requisite quality? For example, 90 percent of the steel bolts and fasteners employed in American construction industries (and other industries such as transportation) are manufactured abroad. Recent spot checks made by two reliable laboratories at the request of the Industrial Fastener Institute found an unacceptably high percentage of defective products. We have no agency in this country that is charged with assuring the American consumer that foreign-manufactured components and equipment meet

U.S. specifications. How do we achieve such assurance?

5. The three nationally recognized model code organizations are receiving increasing numbers of reports of counterfeit products, manufactured abroad, which carry the organizations' symbols and numbers for compliance reports or product analysis reports that do not exist. Why can't our customs inspectors delay distribution of such products at their ports of entry until there can be a confirmation that they have been properly tested ?

Those of us who are close to the construction sector are aware that foreign interest in the U.S. market is growing. In Dallas last December at the annual convention of the National Association of Home Builders, 124 of the 950 exhibiting supplier companies were from abroad.

Foreign Investment in U.S. Real Estate

"I'll Take Manhattan--and Waikiki" read the headline of TIME magazine's March 1987 report that Japanese investors are moving into the real estate markets of New York, Honolulu, and other major cities. Paying sums TIME labelled "spectacular" and buying at a fast rate, the Japanese spent more than $4 billion for U.S. real estate in 1986, more than four times what they spent in 1985.

TIME's story was of Japanese investors buying some of these cities' most prestigious buildings. Another story, in the

Wall Street Journal in April, was of three Japanese banks or bank consortiums being selected by non-Japanese developers to finance mega-developments in Dallas, New York, and San Francisco.

Although recent press coverage of foreign investment in U.S. real estate has focussed on the Japanese, they have not been the biggest foreign investors in our land and buildings. The Urban Land Institute study of total investment from 1979 through 1983 listed the biggest investors, in order, as Canada, the United Kingdom, the Netherlands and Netherlands Antilles, West Germany, and Japan.

It is by no means clear that Japan or any other country is buying up the United States. The sums foreigners are investing are, as TIME called them, spectacular: $610 million for the Exxon Building in Rockefeller Center, $145 million for 50 percent of the Crocker Bank Tower in San Francisco, $620 million for Arco Plaza in Los Angeles. But they are but a fraction of the mammoth market, which in the last ten years alone saw nearly $250 billion of new office construction.

Canadians, too, have been active investing in U.S. real estate. In an article entitled "The Canadian Impact on the U.S.", Edward Christman reported in the March 1987 issue of Shopping Centers Today that "In all, the five Canadian (retail development) companies already in the United States, directly and indirectly, own about 65 million square feet of gross leasable area in retail properties." This is out of an estimated total

U.S. retail real estate of 3.8 billion square feet.

The Canadian firms either moved directly into operations in the United States or acquired part or all of existing American firms. For example, Trizec of Calgary, Alberta, acquired 100 percent of The Hahn Company of San Diego and approximately 25 percent of The Rouse Company of Maryland, which, with 68 centers holding 39.5 million square feet of gross leasable area, is probably the single largest American retail developer.

"Many of the developers interviewed said that they were already in the United States through the office building market and saw shopping centers as the next logical step for diversification." Christman wrote that there are indications Japanese investors will follow this pattern.

The background to the southward migration of Canadian developers illustrates some of the comparisons between U.S. firms in the construction sector and their foreign competitors, and it bears brief rendition here.

The Canadian movement into the U.S. market began at the outset of this decade. Canada's comparatively small population had absorbed all the retail centers it could use, and Canadian companies were looking for new opportunities to invest their considerable resources of money. Because they are publicly traded, Canadian firms have credit ratings and the ability to issue stocks and bonds to raise capital.

American development firms, being largely private, have

to raise money on a project by project basis. And, unlike their American counterparts, Canadian and other foreign banks are allowed to hold equity positions in the projects they finance.

I suggested earlier that I do not believe there is cause for alarm at this juncture over the level of foreign investment in U.S. real estate or in U.S. real estate development firms. Seen nationally, ours is a large and diverse market that will, I believe, resist domination by any one group of investors.

There are, however, possible consequences from these developments about which we should be concerned and into which the NIBS task force is inquiring.

First, as the Canadian and Japanese stories make clear, the way in which an industry is financed has a direct bearing on its competitiveness internationally. In the case of Canada, firms have access to a plentiful and steady flow of investment capital. In the case of Japan, money presently costs one-third of what it costs in the United States. In both cases, our competitors are better financed for the long race than we are.

The second possible consequence is that foreign investors will call the development tune, that is, will specify foreign architects, designers, engineers, contractors, and materials suppliers for their projects. There now are signs that some foreign investment capital is coming into this country with strings attached to foreign professionals and firms and without providing an opportunity for U.S. firms to bid competitively.

For instance, Japanese contractors did $1.7 billion of work in this country in 1985, an undetermined fraction of it at the behest of Japanese investors.

Indeed, in an interview with Engineering News Record, Makoto Uzawa, manager of the planning department of the international division of a major Japanese construction firm, said that Japanese contractors will continue to be drawn to the United States, constructing facilities for long-time Japanese clients which have moved manufacturing operations to the U.S., and for Japanese banks, insurance firms, and investment portfolio managers, which see U.S. offices and buildings as low risk investment.

The third possible consequences of foreign investment in U.S. real estate relates, again, directly to the fact that financing is a determinant of competitiveness. It is that foreign ownership of concentrations in local markets could drive those markets. Assume for the moment that it is true as reported that Japanese investors own 20 major office buildings in downtown Los Angeles. Because capital costs them less, they could be willing to accept lower rates of return on their investment than American investor accept. By virtue of this fact, they would be in a position to hold office rental rates below market and virtually curtail new construction and investment except by those investors--in all likelihood foreigners--willing to accept comparably low returns.

It is into such issues as these that our task force is delving.

Foreign Entries in U.S. Construction Markets

The United States is an attractive market to overseas construction firms. Of the estimated $134 billion in construction contracts awarded in the United States in 1985, $7.3 billion went to 59 foreign contractors, according to Engineering News Record. That is a 27 percent increase over 1984 and more than double the amount in 1983.

Of those 1985 contracts, Japanese firms accounted for $1.7 billion, and more than 70 percent of this sum represented work done for Japanese clients or Japanese-American joint venture clients.

Although the Japanese figure has been more often quoted than that for any other country, it is slightly less than the $1.9 billion accounted for by two German firms, Philipp Holzmann A.G. of Frankfurt and Bilfinger-Berger Bau A.G. of Weisbaden, which are channeling their entry into the American market through established American firms they acquired.

French firms, as well, are buying American building firms just as I reported earlier Canadian firms are buying American retail developers. The Finns have gone into partnership with the Passamaquoddy Indians of Maine to build and market industrialized housing in the Northeast, having decided they can eliminate some

of the obstacles that slowed the Swedes' expansion into this market. The British and Italians, among others, are doing increasing amounts of business within our borders. Yugoslavia recently won a competition to provide a steam generating plant for the U.S. Naval Base in Norfolk, Virginia with a bid that was 50 percent lower than the next bid.

In the early 1970s, three diversified British-based construction firms entered the California market: Barratt, Taylor-Woodrow, and Wimpy. Daon and Cadillac-Fairview, two Canadian firms, entered the U.S. market about the same time. At one time, Europe's largest homebuilder, Maison Phenix of France, owned 18 percent of the stock of our nation's largest home builder.

The list of examples is much longer, but reciting it is less important than understanding what this entry--some say penetration--means.

The question is whether this degree of entry by foreign firms is good or bad for the American economy and the construction sector of it.

The answer is that we do not know enough yet to answer that question, although several organizations are gathering information in this field. The Building Research Board of the National Academy of Sciences is looking at competitiveness issues in international construction. The Office of Technology Assessment is completing a study of international competition in

engineering and construction. The National Association of Home Builders is winding up a first look at foreign entries in American residential construction markets.

But much more work is needed if we are to know enough to answer a host of policy questions. Among them are these.

Some respectable and knowledgeable authorities have assured us that the advent of foreign investors and their contractors is creating more and greater opportunities for U.S. firms to co-venture projects that only foreign capital can bankroll.

These authorities do not, however, tell us whether the capabilities of important elements of the U.S. construction sector will be permanently altered for the worse by what one Engineering News Record editor has called foreign "economic imperialism."

Will the result be a replay of what happened to the American automotive industry? Or the U.S. shipbuilding industry? Or the steel industry?

Will the U.S. design and engineering industries be largely displaced over time by the favored industries of foreign investors?

What limitations can or should be placed on the inflow of investments? Are such limitations likely to produce more harm than good to the U.S. economy and its construction sector?

These are among the questions we seek to answer

prospectively so that the answers will not have to be learned later in painful retrospection.

Productivity and Quality of the U.S. Construction Industries

> Building--the planning, design, and construction of new facilities as well as the ongoing repair and rehabilitation of existing facilities--is especially important. We invest over $300 billion in newly constructed homes, nonresidential buildings of all kinds, industrial and utility plants, highways, and other transportation facilities each year. The productivity of the construction industry directly influences the productivity of every segment of the American economy.
>
> from "Construction Productivity"
>
> National Research Council
>
> 1986

It is fitting that I end this testimony on the subjects of the productivity and quality of the construction industries in the United States for it brings me, I am sorry to say, full circle to the topic with which I began, research and development.

For, despite the economic and social potency of these industries to achieve good or do ill, we know very little about these subjects beyond what those of us who have been around for a long time can intuit:

* The construction sector of the U.S. economy is productive in the sense that it is able to work within the strong swings in demand for its products and still survive without the

kinds of massive subsidies the agriculture industry has required.

* The quality of the products--especially the buildings in which Americans spend 80 percent of their lives--ranges from excellence to something less.

* The industries, which is to say the owners, managers, suppliers, regulators and labor that constitute the construction sector, are conservative and resistant to change, not unlike the automotive industry from after the second World War until the beginning of this decade.

* The industries' output, especially of housing, is uneven in response to demand, especially at the lower end of the income scale.

In this regard, I believe it is important to cite a survey by the U.S. Conference of Mayors that reported that 31 percent more families requested emergency housing last year than in the year before. The survey said that joblessness was not the sole cause of homelessness. Every one of the 29 major cities surveyed listed lack of affordable housing as one of the main causes of homelessness.

The NIBS task force will pursue the issue of affordability of all types of construction in the U.S. in an effort to identify what we suspect are deep institutional blockages. We will scrutinize the institutions of finance and regulation as well as the pertinent elements of the construction

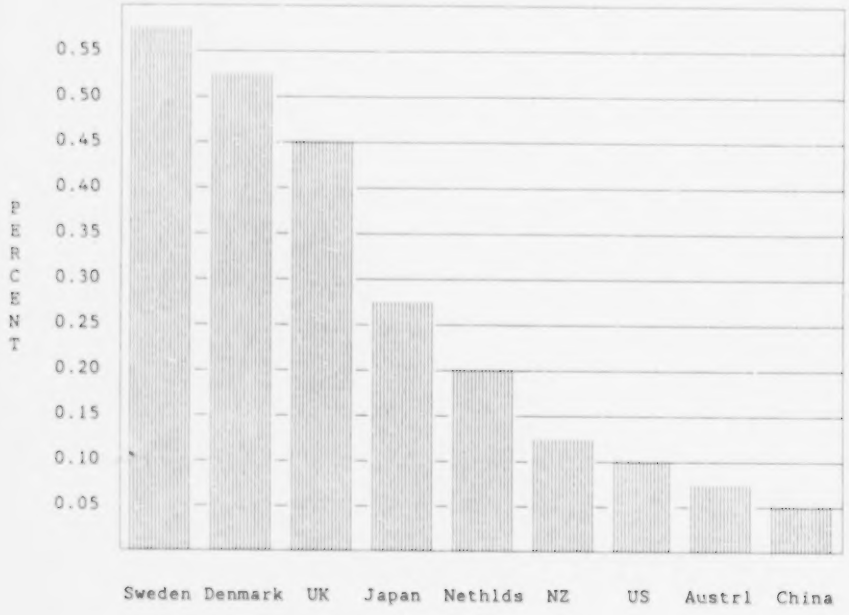
sector.

We will look to other countries for clues as to how to remove these restraints and help the construction industries both compete successfully internationally as businesses and contribute to the quality of life as American institutions.

APPENDIX A

CHART 1

PERCENTAGE OF CONSTRUCTION R & D
TO GROSS TOTAL VOLUME OF CONSTRUCTION, 1981-82

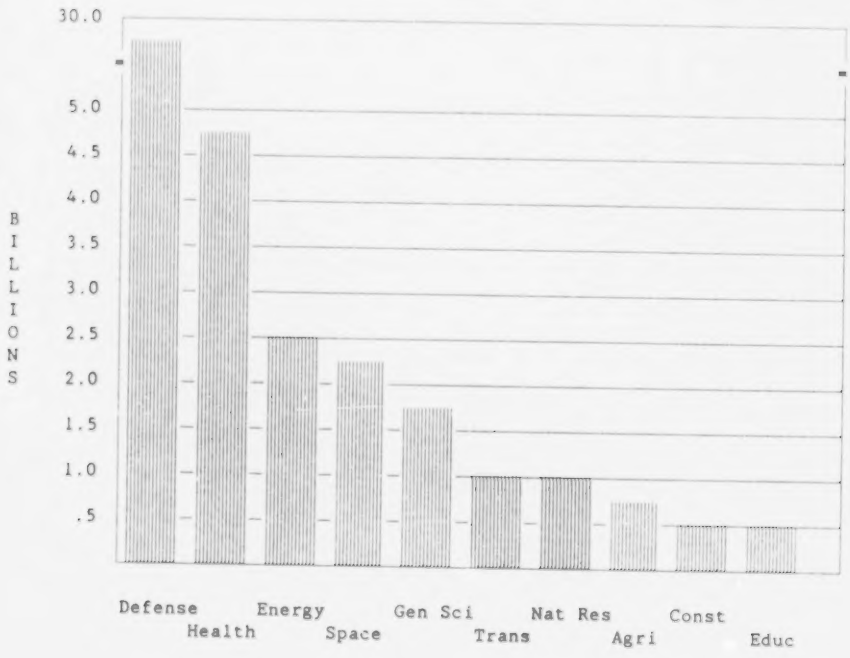


	%
SWEDEN	0.57
DENMARK	0.53
UNITED KINGDOM	0.45
JAPAN	0.28
NETHERLANDS	0.21
NEW ZEALAND	0.14
UNITED STATES	0.12
AUSTRALIA	0.07
CHINA	0.03

Source: Building Research and Development Record, Building Research and Development Advisory Board, Australian Department of Housing and Construction, Canberra, 1986, p.19.

CHART 2

FEDERAL RESEARCH & DEVELOPMENT EXPENDITURES, 1984

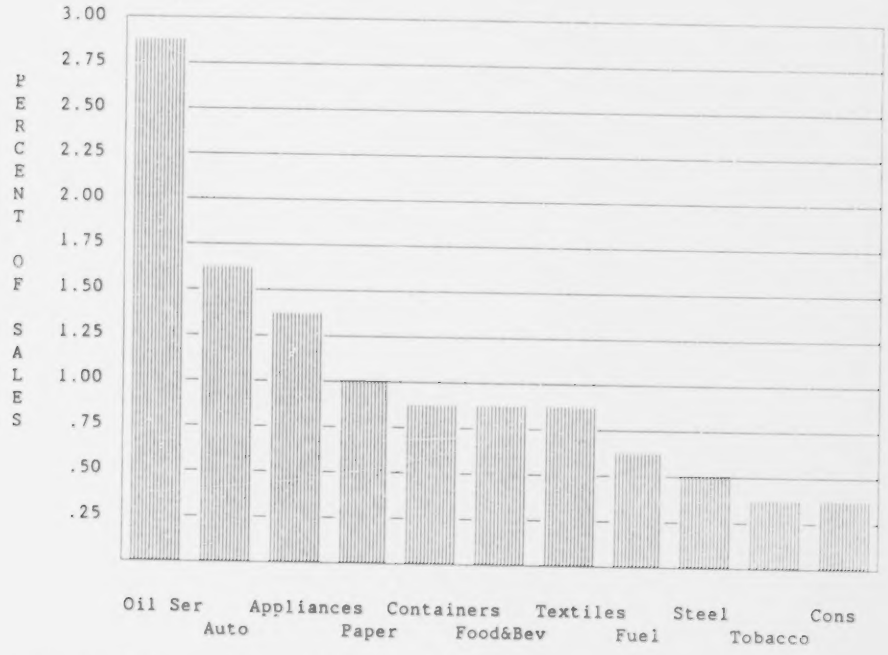


	BIL $		BIL $
DEFENSE	29.29	TRANSPORTATION	1.04
HEALTH	4.78	NAT. RESOURCES	.96
ENERGY	2.58	AGRICULTURE	.76
SPACE	2.30	CONSTRUCTION	.22
GENERAL SCIENCE	1.68	EDUCATION	.20

Source: Schwartz, J., "Federal R & D Funding by Budget Function", Washington Post, December 10, 1985, p. a-19.

CHART 3

RESEARCH & DEVELOPMENT EXPENDITURES BY U.S. INDUSTRY, 1984

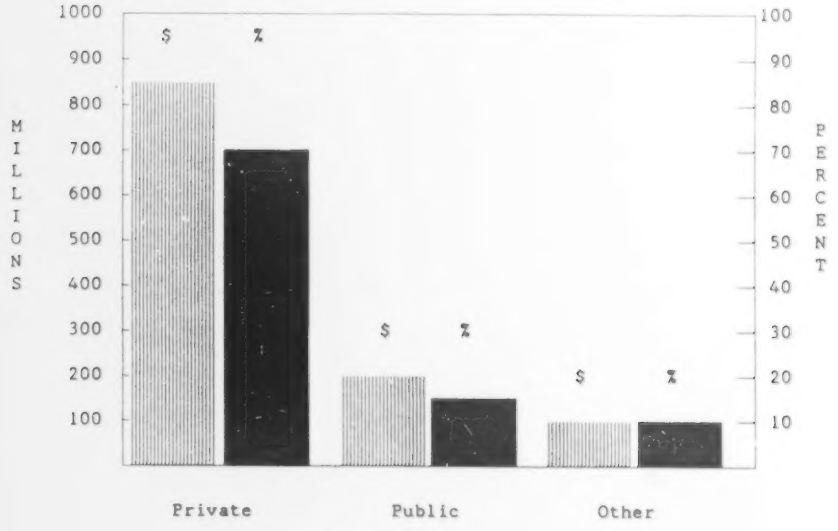


OIL SERVICE & SUPPLY	2.90	TEXTILES	0.80
AUTOMOTIVE	1.70	FUEL	0.70
APPLIANCES	1.40	STEEL	0.50
PAPER	1.00	TOBACCO	0.40
CONTAINERS	0.90	CONSTRUCTION	0.39
FOOD & BEVERAGE	0.90		

Source: "R & D Scoreboard", Business Week, July 8, 1985, pp. 88-106.

CHART 4

U.S. CONSTRUCTION R & D EXPENDITURES, PUBLIC AND PRIVATE

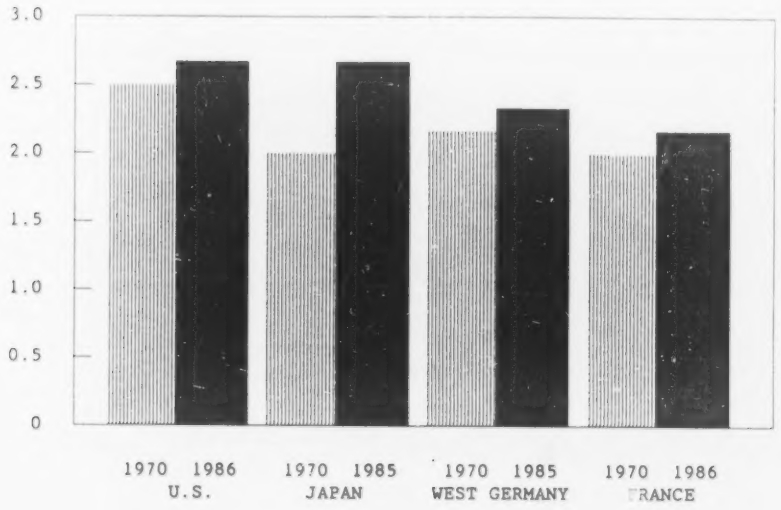


	(Millions $)	(% of Total)
FEDERAL FUNDING	220	18
PRIVATE FUNDING		
Contractors	54	4
Manufacturers	838	69
PRIVATE FUNDING TOTAL	892	73
OTHER SOURCES	111	9
TOTAL	1.22 BILLION	100

Source: Construction Productivity, National Research Council, 1986, p.41.

CHART 5

PERCENTAGE OF GNP SPENT ON RESEARCH AND DEVELOPMENT
(includes military research and development funds)

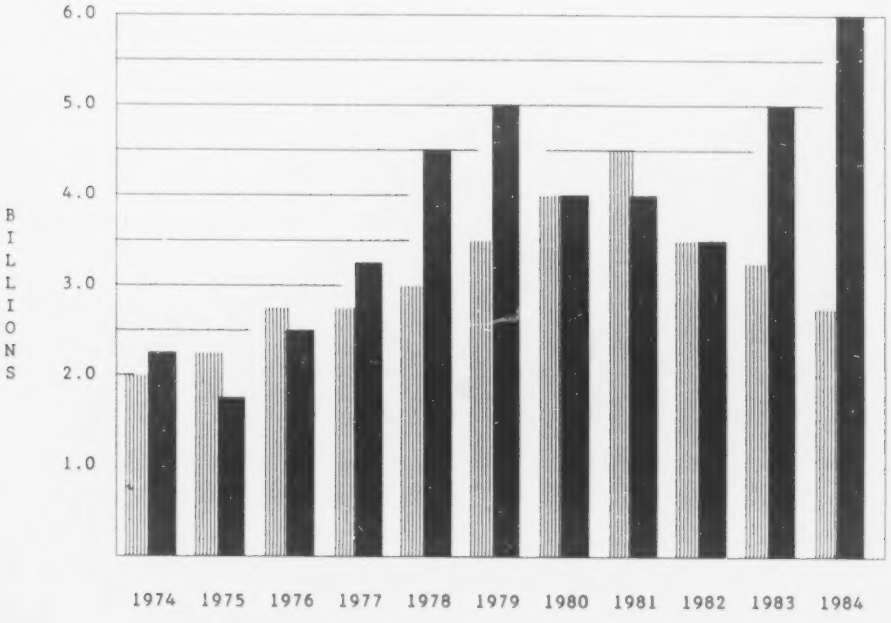


	1970	1985 OR 1986
UNITED STATES	2.6 %	2.8 %
JAPAN	1.9	2.8
WEST GERMANY	2.1	2.6
FRANCE	1.9	2.4

Source: The National Science Foundation

CHART 6

U.S. IMPORTS AND EXPORTS - SELECTED CONSTRUCTION MATERIALS
1974-1984



BILLIONS $

	EXPORTS	IMPORTS
1974	2.03	2.17
1975	2.13	1.67
1976	2.61	2.40
1977	2.76	3.23
1978	2.95	4.32
1979	3.56	4.84
1980	4.09	3.96
1981	4.40	4.09
1982	3.62	3.57
1983	3.24	4.99
1984	3.01	5.93

Source: Pitcher C.B., Stanley G.," U.S. Foreign Trade in Construction Materials" Construction Review, May/June 1985, p.4

APPENDIX B

FOREIGN INFLUENCES TASK FORCE

Chairman: David Smith
David Smith Builders
Past President NAHB

Barbara T. Alexander, CFA
Salomon Brothers
New York

Barry Berkus, AIA
Berkus Group Architects
Santa Barbara, Ca.

William S. Birney
Consultant
Maryland

Dr. Eric Dluhosch
MIT School of Architecture and Planning
Cambridge, Mass.

John P. Eberhard
National Academy of Sciences
Washington, D.C.

Deane Evans
Steven Winter Associates
New York

Dr. Charles Field, Esq .
National Association of Home Builders
Washington, D.C.

Ronald Gebhardt
Consultant
Sewickley, Pa.

Bob Gold
Office of Technology Assessment
Washington, D.C.

Sanford R. Goodkin
The Goodkin Group
La Jolla, Ca.

Dr. Larry Grosse
Department of Construction Science
Texas A&M University

Joseph Honick
Group Management Associates
Encino, Ca.

Foreign Influences Task Force - 2

Ralph Johnson
NAHB Research Foundation, Inc.
Maryland

Ron Kabot
Salomon Brothers
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Dr. Frederick Krimgold
School of Architecture
Virginia Tech

Eugenia M. Lee
Peat, Marwick, Main & Company
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Robert W. Lisle
The Travelers Insurance Department
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John Lynch, CFA
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Renee Mathieu
International Trade Administration
U.S. Department of Commerce
Washington, D.C

Jackson McDaniel
McDaniel Development
Orlando, Fl.

James Powers
Lone Star Industries, Inc.
Greenwich, Ct.

Stan Ross, CPA
Kenneth Leventhal & Company
Los Angeles, CA

John Slayter
The Ryland Group, Inc
Columbus, Ohio

Harvey J. Sorum
Dow Chemical USA
Charlottesville, VA

Foreign Influences Task Force - 3

David Haviland
Dean
School of Architecture
Rensselaer Polytechnic Institute
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Bob Wibel
NCS/BCS
Herndon, VA

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RENE A. HENRY JR.
President and Chief Executive Officer

Rene A. Henry Jr. is president and chief executive officer of the National Institute of Building Sciences (NIBS). He took office on January 5, 1987, the Institute's second president in its 10-year history, succeeding Gene C. Brewer.

Henry has more than 25 years of experience in management, marketing communications and financial and governmental relations. He has served as a consultant in virtually every area of the building and construction industry, including builders and developers of residential, commercial and industrial properties; architects; and building materials manufacturers and has worked with industry trade associations; government regulatory agencies; elected and appointed government policymakers at the federal, state, and local levels; and lenders and investment bankers. He has consulted on systems technology, development, financing, and marketing both nationally and internationally.

Before joining the Institute, he was a California-based management and marketing communication consultant to companies and organizations in the building sciences and other fields. He also is well known for his contributions in the area of sports marketing.

A member of the U.S. Olympic Committee (USOC), he serves as a special advisor for the president of the USOC as well as on three committees: International Relations, Long-Range Strategic Planning Task Force, and Public Relations/Media Information. He directed the international communications campaign that led to the selection of Los Angeles as the site of the 1984 Olympic Games.

He also is a special advisor to The President's Council on Physical Fitness and Sports, a member of the Institute of Residential Marketing of the National Association of Homebuilders, and a member of the Academy of Television Arts & Sciences.

He is the author of How to Profitably Buy and Sell Land, published in 1977 by John Wiley & Sons, as well as a number of reports and articles. The recipient of numerous awards in marketing and for creative excellence, he was awarded the Distinguished Citizen Award in 1980 from the Los Angeles Chapter of the Public Relations Society of America, and the Clarion Award for Human Rights from Women in Communications. He has been honored nationally and internationally for documentary and sports films he has created and produced.

Born in West Virginia, he grew up and attended high school in Norfolk, Virginia, received his A.B. degree in economics from the College of William and Mary, and did graduate study in marketing at West Virginia University, Morgantown.

His biography is listed in "Who's Who in America" and "Who's Who in Finance and Industry."

Mr. ADAMS. Thank you, Mr. Chairman.

I am Harold Adams, the President of RTKL Associates. RTKL is among the larger architectural and engineering design firms in this country with five offices across the United States. So I have firsthand familiarity with what is happening nationally and internationally within our profession.

This morning I am representing the American Institute of Architects, of which I am a member. Because we have 52,000 members, the AIA is able to draw upon an in-depth knowledge of its members in preparing for this testimony. We have submitted our written views for the record, and now I would like to summarize just a few points.

For purposes of clarity, I divide my topic into two discrete areas: One is the domestic impact of foreign competition. The other is competition from foreign firms in the foreign marketplace itself.

First, foreign penetration of the U.S. domestic market is on the rise. In our design professions, the foreign interest buy a major share in American firms, usually well known and major ones. Acquisition or merger seems to be the easiest, most efficient, and most profitable way to enter this market of ours.

In the past five years, British, French, Swiss, West German, Dutch, Lebanese, and Saudi interests have all entered our market in this manner.

By doing this, they acquire firms with U.S. know-how, fully licensed to practice in the United States, staffed with registered professionals, and which firms have all had excellent reputations as leaders in their fields, and the foreign owners avoid all of the enormous start-up costs of entering for the first time a new market.

The Canadians, because of their easy access into this country, have not made large scale purchases of U.S. firms. They have simply opened offices and proceeded to accommodate the major Canadian developers which have already been mentioned as having major projects in this country.

During this same period of time, I should mention that Canada has not allowed reciprocal ease of access for us to do work in Canada.

Throughout this same period, the Japanese have quietly entered the U.S. market in a major and different way. The form of entry is by the very large Japanese construction firms who come in and offer design, build and financing. To date, the Japanese have used American architects for local problems. Sometimes to do the design. But more and more the design is going to be done by their enormous architectural and engineering staffs back in Japan, and then shipped here to be built.

It is important to emphasize that the Japanese do not allow our firms into their closed design and construction economy. This should be a major focus of your subcommittee's inquiry.

And now I would like to turn to the second broad area, the international arena. In itself, a tapestry of difficulties and complexities of all kinds.

There the market share for U.S. architects and engineers is rapidly decreasing. Without question, the number one obstacle overseas is foreign government subsidization of their own national firms. Massive subsidy programs are offered design firms from

Japan, Korea, West Germany, France, the U.K., Holland and Spain. And this gives them an overwhelming advantage over their U.S. counterparts and competitors.

By comparison, U.S. government aid to firms is very minor.

Tariffs and taxes also hinder U.S. architects and engineers in some countries. The Canadian tariff on architectural engineering drawings, at least until recently, could amount to hundreds of thousands of dollars. This potential of enormous duties led to the harassment of U.S. architects and engineers and confiscation of their drawings at the border.

More subtle barriers present other difficult obstacles. Perhaps the most—the foremost are the different linguistic, financial, business, ethical, political and cultural landscapes encountered abroad. But all of this is to ignore the obvious. If America is to be competitive globally, America must accept the fact that the nature of the game changes. The world does not and will not mirror the American design world, its culture, its habits, its time zones, its language, and its technology. So we have to adapt to the real world beyond our shores. If we want to do business globally, we have to acquire global sophistication, just as our competitors do. And here we need the support in R&D programs.

The international marketplace is a complicated mosaic, but the bottom line is that U.S. architects and engineers are losing the trade battle, both at home and abroad. U.S. design firms now get foreign business in only two situations: where they have an excellent reputation, and technological advantage. The second is where there are U.S. government set-asides.

Our technological advantage is diminishing rapidly as foreign firms joint-venture with U.S. design firms and learn our technology. We need to work toward ending this downslide.

We in the AIA support and commend the committee's efforts, and we appreciate this opportunity to make this presentation.

Thank you.

[The prepared statement of Mr. Adams follows:]

STATEMENT OF THE GLOBAL COMPETITIVENESS OF THE AMERICAN DESIGN PROFESSIONS

By

Harold L. Adams, FAIA

For

THE AMERICAN INSTITUTE OF ARCHITECTS

Before the

SUBCOMMITTEE ON SCIENCE, RESEARCH
AND TECHNOLOGY OF THE COMMITTEE
ON SCIENCE, SPACE AND TECHNOLOGY

June 4, 1987

Mr. Chairman and members of the Committee, I am Harold L. Adams, President of RTKL Associates, and a member of the American Institute of Architects. RTKL is among the larger architectural and engineering design firms, having five offices across the United States. As a result, I have first-hand familiarity with what is happening nationally and internationally within our profession.

The AIA represents some 52,000 members of the architectural professional and has in-depth knowledge of what is affecting its members in the domestic and foreign marketplace. The AIA is also a member of the International Engineering and Construction Industries Council (IECIC), an international trade coalition which also represents the American Consulting Engineers Council, the Associated General Contractors, and the National Constructors Association. IECIC has prepared a competitiveness plan for the design and construction industry, copies of which we have available here today.

This morning, I will be presenting the views of the AIA concerning foreign penetration of the U.S. design market and U.S. penetration of the international design market. I will be listening with great interest to what my fellow witnesses have to say.

And now to the matter at hand. For purposes of clarity, I will divide my topic into two discrete areas. One is the domestic impact of foreign competition, the other is the foreign marketplace itself.

First, foreign penetration of the U.S. domestic market is on the rise. This is confirmed by statistical trends from 1980 through 1985 showing dollars earned by foreign architectural and engineering firms in our country. According to International Construction Week, the billings of top foreign design firms in the U.S. have increased as follows:

Millions of dollars

1980	1981	1982	1983	1984	1985
58.8	59.7	91.1	74.3	97.7	115.4

Thus, foreign firms have practically doubled their U.S. billings over a six-year period.

In our profession, as documented by the Professional Services Management Journal, this penetration is usually taking the form of acquisitions and mergers -- foreign interests buying a major share in American firms, usually well-known and major ones by the way. Acquisition or merger seems to be the easiest, most efficient and most profitable way to enter the U.S. market.

In the past five years, British, French, Swiss, West German, Dutch, Canadian, Lebanese, and Saudi interests have all entered our market in this manner. French interests bought a very large A & E firm headquartered in Nebraska. Swiss interests acquired a strong local firm based across the river in Alexandria, Virginia. Lebanese interests purchased a major national A & E firm

in Chicago. Saudi interests bought into a very large national, indeed international, A & E firm based in Houston, Texas. The West Germans and Dutch just recently bought substantial, up to 50 percent, interests in excellent engineering firms, one based in Houston, one in suburban New York, one in South Carolina, and the fourth in California.

By doing this, they acquire firms which already have the U.S. "know-how", have been duly licensed to practice around the United States, are already staffed with registered professionals who are knowledgeable about the intricacies of local codes and laws, and which firms have all established excellent reputations as leaders in their fields. And the foreign owners avoid all the enormous "start-up" costs of entering, for the first time, any new market. Apparently, due to the relative size of the U.S. design market compared to that of other countries, foreign design firms find the purchase of U.S. design firms to be highly attractive. In contrast, the purchase of foreign design firms is less desirable to U.S. firms.

The Canadians, because of their ease of access into this country, have not made large scale purchases of U.S. design firms and in a few cases opened local offices to accommodate some of the Canadians developers who were heavily involved in U.S. projects. Incidentally, for most of these years, Canada did not offer reciprocal ease of access to U.S. firms seeking to work in Canada, a point that I will touch upon later.

And throughout this period, the Japanese have quietly entered the U.S. market in a major way. The form of entry is by the very large Japanese construction firms who come, offer "design/build" packages and most important of all, offer very

attractive financing. In 1985, the Japanese share of the construction market was $1.8 billion and by 1986, one year later, it had grown to at least $2.5 billion dollars.

To date, they have used American architects to handle code conformity and local problems, and sometimes to do the design work. However, the design work is increasingly done by their own enormous architectural and engineering staffs back in Japan and shipped over here to be built.

The diversity of their work is great: major projects in Minnesota, Ohio, California, Michigan, New Jersey, and Tennessee. And these are prestige projects -- for example, Shimizu, a huge firm, recently landed a $40,000,000 "design/build" job for the Xerox Corporation.

Some knowledgeable people believe that the Japanese represent the real threat to our American firms -- to our own architects, engineers, and contractors living and working in what is the largest design and construction market in the world today, the United States. Moreover, Japanese contractors have had success recently in hiring top U.S. architects and engineers away from their U.S. firms. And it is important to emphasize that the Japanese do not allow our firms into their closed design and construction economy.

Now I would like to turn to the second broad area, the international arena, in itself a tapestry of difficulties, intricacies and complexities of all kinds.

Without question, the number one obstacle overseas is foreign governments' subsidization of their own firms. Export subsidies can and do include the following:

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Export credits and grants for feasibility studies and bid proposals, government guarantees on bid bonds and performance bonds and guarantees against the loss of bids.

Export credits blended with foreign aid to provide loans at very low interest rates.

Government risk sharing including government insurance or reinsurance of commercial and political risks.

Discriminatory taxes on profits of foreign firms or on imports of goods and services.

These massive subsidization programs are offered design firms from countries such as Japan, Korea, West Germany, France, the U.K., Holland, and Spain. And the result is to give them an overwhelming advantage over their U.S. counterparts and competitors.

U.S. Government aid to U.S. firms--for example, concessionary financing by the Export-Import Bank, overseas project feasibility studies by the Trade and Development Program, and political risk insurance from the Overseas Private Investment Corporation--is miniscule in scale compared to the subsidization programs of other countries.

Efforts by foreign governments to get their design firms international business do not just end with subsidization. Their embassies and chanceries help their

nationals find projects and financing. U.S. embassies sometimes help U.S. architects and engineers, but not to the same extent.

Furthermore, firms from the same country may collude among themselves so that only one will compete for a given project in another country. In that way, they avoid competition where they may eliminate each other. Accordingly, U.S. design firms and the U.S. Government must learn to work together overseas.

Another major obstacle is preferential treatment for their own nationals in their own country. This has become an imposing barrier in the last five years due to the global recession and resulting protectionist fervor to ensure that their own design firms have business. This preferential treatment in Third World countries can take the form of a requirement of participation by local architects and engineers. Local participation can lead to technology transfer, thus diminishing the technological advantage that we have enjoyed in the past.

Tariffs and taxes hinder U.S. architects and engineers in some countries. The Canadian tariff on architectural/engineering drawings, at least until recently, could amount to hundreds of thousands of dollars. The potential of enormous duties involved led to harassment of U.S. architects and engineers and confiscation of their drawings at the border.

One American architect had a Royal Canadian Mounted Policeman telephone from Canada demanding that he be allowed to search the architect's New York office for evidence of tariff violation. Another architect was arrested at the border for "smuggling" blueprints. By way of contrast, the U.S. has no tariff on architectural/engineering drawings.

As for punitive taxes, India has a 40% tax on technical services imposed on foreign firms unless the project is funded by the World Bank, the Asian Development Bank or similar lending institutions. Mexico also has a tax on work performed.

More subtle barriers present other difficult obstacles. Perhaps foremost are the different linguistic, financial, business ethic, political and cultural landscapes encountered abroad. For example, some countries do not allow compensation for design services to be taken out of the country if it is in the form of the local currency.

But all this is to ignore the obvious. If America is to be competitive globally, America must accept the fact that the nature of the game changes; that the world does not and will not mirror the American design world, its culture, its habits, its time zones, its language and its technology.

We have to adapt to the real world beyond our shores. If we want to do business globally, we have to acquire global sophistication just as our competitors do. And as far as I am concerned, the sooner we do that, the better.

In the complicated mosaic that is the international marketplace, the bottom line is that U.S. architects and engineers are losing the trade battle, both at

home and abroad. U.S. design firms are now getting foreign business in only two situations: (1) where they have an excellent reputation or technological advantage; and (2) on U.S. government set-asides. Moreover, our technological advantage is diminishing rapidly as foreign firms joint venture with U.S. design firms and learn their technology.

We need to work toward ending this downward slide.

The AIA supports you and commends the committee in your efforts to address the trade problems in our design and construction industry. And we appreciate the opportunity to make this presentation on behalf of our architectural profession.

And now I would be glad to answer any questions you might have.

BIOGRAPHICAL SKETCH OF HAROLD L. ADAMS, FAIA

Harold L. Adams, FAIA, is President of RTKL Associates Inc., one of the country's largest architectural and design firms. A Principal of the firm since 1968 and member of its Board of Directors since 1969, Mr. Adams has directed RTKL's growth to a highly successful international practice with offices in Baltimore, Maryland; Dallas, Texas; Washington, D.C.; Fort Lauderdale, Florida; and Los Angeles, California. Over 500 professionals are employed by RTKL, working on more than 300 current projects.

Elected in 1983 to the College of Fellows of The American Institute of Architects, he has served the AIA on the national, state and local levels. He is currently Chairman of the AIA's Large Firm Roundtable.

Mr. Adams also serves on the Boards of Morgan State University, The Maryland Institute College of Art, and The Baltimore City Life Museums, all in Baltimore, Maryland. He is a Trustee of The Walters Art Gallery and President of the Economic Development Council of the Greater Baltimore Committee.

Mr. VALENTINE. Thank you, Mr. Adams.

Mr. Adams, what major building components are being imported into the United States? Are we talking about structural components, architectual components, or both, or something else?

Mr. ADAMS. I can speak on the architecture and the engineering components. As I stated, in the past there has not been a great deal of that technology coming in, but we are now experiencing and have first-hand knowledge of at least in one instance where the engineering is being produced back in Japan for major projects in this country, and we see a trend in that direction. Certainly many of the building components, steel, structural steel, reinforcing steel, and many other components of those market share have already been lost.

Mr. VALENTINE. At least two of you have alluded to the unfair competition—I think that is the way you have characterized it—that we experience concerning our neighbor and ally to the north, Canada, and in the small city close to which my home is located in eastern North Carolina, a fast food chain by the name of Hardee's originated there. That company has been owned by a Canadian corporation, Hardee's has, for several years. A big shopping center, even by national standards, was erected in that city of about 50,000 some thousand people by a Canadian firm recently.

Why, all of a sudden, so much competition, so much Canadian activity at almost every level in this country? Much more so, apparently, than was the case five years ago or 10 years ago. Mr. Henry?

Mr. HENRY. Mr. Valentine, the Canadians have been in our marketplace for a number of years, not only with single family homebuilders, going back 17 years ago to the early '70s, with Daon and Cadillac-Fairview, which was not only into housing, but into commercial and other types of structures. The Canadians have been here a long time. One, the interest rates here have always been lower than in Canada, except when interest rates went up to 19 percent and the low 20s percent.

The United States also has been a bargain for investment in real estate and land compared to the rest of the world. The opportunities here are tremendous. Our real estate is the best buy anywhere in the world. Now we find a great deal of foreign money coming into the U.S.

One, they are willing to accept less of a return on investment. Asians will take 1 to 3 percent return on investment where we need closer to 10 percent to make the numbers work.

When you look at the devaluation of the dollar, it's even cheaper money for foreigners to buy our real estate.

Mr. VALENTINE. You don't have the name of any Canadians? I have a little tobacco farm in eastern North Carolina that's not getting along too well. I might contact one of them.

[Laughter.]

Mr. VALENTINE. Mr. Roe.

Mr. ROE. I think there's a factor that we cannot overlook. In the United States we tend to emphasize our problems to ourselves, and we probably don't give ourselves a fair shake as to what we really are.

The fact of the matter is we are one of the best markets in the world for many, many things. And what I have found over many

years in this business is that places like Canada and England and other folks where they don't have a great market at home, they go where the good market is.

Now I can echo exactly what he has to say, because I am licensed to practice, and it's amusing, in 20 states in America, I can practice in England and Australia. And we have had projects in Canada, and it's extremely difficult to get a license to practice in Canada. And when you do, it's only on a single project basis. When the project is done, the license is gone.

So exactly what my colleague says is true. The borders here are open. The borders going back into Canada are not.

Mr. VALENTINE. Well, Mr. Roe, why can't the President, why can't the Chief Executive—you know, we tried to do something about these things, and they said, these things will take care of themselves, we're going to have free trade. Why can't we—don't we have sufficient statutory authority now to say to the Canadian people, what you do to us we will do to you? Wouldn't that be a fair thing to do?

Mr. ROE. Well, Mr. Valentine, you can. But let me take the issue of licenses. Licenses in Canada and licenses in the United States are states' rights matters, they are not national jurisdiction. The reason I have had to have 20 licenses is because each state has its own authority to decide whether I am a professional engineer. I guess you might say I am. But I have to go to any new state and prove it. The same thing happens in Canada, where it's done again as a states' rights matter. So the governments could say we are going to do this, but the states have their own authority. That might make it difficult. I don't happen to like it, but that's the way the business is.

Mr. VALENTINE. Well, sir, that's a mighty discouraging pronouncement. You say that because of the internal political structure, there may be nothing we can do about these things.

Mr. ROE. Well, some years ago the Congressman from New Jersey in my section, I asked him would he try and do something to get a national license to practice engineering, and he just laughed and he said, "You know, that's a states' rights issue. I'm not interested."

Mr. VALENTINE. I would never say I'm not interested. [Laughter.]

Mr. ROE. I know that.

Mr. VALENTINE. Mr. Miller?

Mr. MILLER. Let us not fall into the trap of looking at the other side of the coin. What we did receive from Canada was some investment of money which we desperately needed at the time when our rates were high. The Canadians brought in money, invested in real estate projects, paid fair prices, and employed a lot of people in the land development and construction business. So that's not all bad. I think we need to look at the sense of balance in that operation, and in some of the areas where Mr. Roe and Mr. Adams referred to, there may be a constraint on the returning side, and that needs to be addressed.

However, in the land development and construction business, I think the Canadian influx of money has been an asset.

Mr. VALENTINE. What about our penetration in this country? What percentages, if you have any information on this, what per-

centage of the shopping centers in Canada are owned by American companies, would you think?

Mr. HENRY. Sir, right now our task force is looking just at the capital inflow into the United States. It has been suggested we also look at the penetration of U.S. dollars and American companies abroad. That is another issue. We will look into it once we complete the study we now have under way.

Mr. VALENTINE. Mr. Roe?

Mr. ROE. I would like to make a comment that somewhat takes off on my colleague in the house building business, which is a good business, I think.

Some years ago the American firms rode on a wave of technological edge, and we went all over the world and we had projects of all kinds and types, and we did that because America had had a big R&D program, and that program provided us a base. That's something I referred to.

There are a number of things that affect whether you get a job at home or abroad, and one of them is if you have a technological edge. I have found over the years the safest thing to do in a foreign market is follow the American dollar. Take a job where you get paid in American currency, where maybe you go down to the Eximbank for money and things like that, because you don't have to deal with the problems of the exchange rate. This indicates that we're not as skillful in some areas as others.

However, unless you have a technological edge, it is very hard to compete with the local folks, and so this is why I emphasize the broad R&D in my discussion.

Mr. VALENTINE. Thank you.

I think, Mr. Adams, you had your hand up a while ago. Do you have anything you want to add?

Mr. ADAMS. Yes. I was going to comment further on the Canadians. I agree with Mr. Miller that the Canadian influence has not all been bad. They have been very fine clients of my own firm, and perhaps we designed the shopping center in your—near your hometown.

The problem has been that some of those firms have wanted to hire American firms to go into Canada and their restrictions were such that it was virtually impossible to do any major work in Canada. The first one is that when you try to cross the border, an American firm tries to cross the border with drawings, the drawings are assessed at the value of the project. If it's a $30 million project, the Immigration authority will want to collect a very major tariff.

Mr. VALENTINE. Well, let me stop you right there. Now that would certainly be a situation where the United States could do the very same thing, could we not, to—under present law, to Canadians?

Mr. ADAMS. I believe that's where something can be done. I think that there are negotiations under way on that subject. I am told that that whole area may be in the process of being clarified in negotiations now. But that's where they have been so restrictive.

Yet on the other side, we have allowed Canadian architects to freely come into this country, to open offices, and to follow their clients.

Mr. VALENTINE. Mr. Henry had his hand up, but I don't want to monopolize this. We will come back to you, but I want to recognize my colleague, Mr. Nagle. Do you have any questions?

Mr. NAGLE. No, go ahead.

Mr. HENRY. I just wanted to add to something Mr. Roe had said earlier. One of our subcommittees came up with information that the United States now funds about half the research done throughout the entire world. This may account for the fact that foreign inventors received nearly half the patents granted by the U.S. Patent Office.

Mr. VALENTINE. Oh, boy. We hear a lot about this problem and we—as I said earlier, it's frustrating, because so many people in the government and outside of the government—it's kind of like a big balloon. You know, you punch it in here and it pops out over there. So many of these places, when you get down to it, they—you find that they are importers of a lot of projects—products, particularly agricultural, which are a significant part of the economy in many areas. But I would like to ask all of you or each of you this question, if you can answer it:

To what extent is American business indirectly a part of this problem, in that—aren't a lot of the companies which have grown up in recent years—and I'm not talking about Canada now, but in Hong Kong, in Singapore, in Korea, if you scratched under the surface, wouldn't you find a lot of American dollars invested in those companies? Wouldn't you find American investors there that have gone to those countries for cheap labor or for other reasons, and in many situations our overseas competition is just an extension of that multinational corporation which has its headquarters in Dallas or in Detroit or New York or Atlanta?

Maybe that was more of a speech than a question, but I'm sorry. Mr. Roe?

Mr. ROE. Let me take a shot at this thing. I'm going to take one country where we have been since the Korean War, and that is Korea. I have seen that country come from a place where they had to come to people like us to design and supervise the construction and buy the material for a cement plant, to the place where they are a real giant in production of many, many things. They got that way largely in many ways because we financed them, we made them grow economically, we helped them. People like us went over and worked there.

When I look at them—and you can see this from what I said in my talk—we look at them as a source of help, where we have to do foreign competition, because in some areas of our projects, it is only a wage rate like theirs that can compete. But I don't find that those companies that we team up with, Hyundai—and you can go mention them, you know all the names—I don't find that they have ownership by American firms.

As a matter of fact, I think if you look into it, you will find it's fairly difficult to get a segment of one of those companies. I am not absolutely certain of that, but it doesn't seem to be the fad right now. So I think in things like garments and consumer goods, there's no question that that happens, but from what I have seen in places like Korea that are emerging, getting strong—Japan,

which is a little bit over the peak now—I find that they are not owned by American companies. I find that we help them.

I'll give you an example. A while back we were trying to build a research—resource recovery plant, and we were looking for financing, and we got an indication of some financing from a Japanese bank. And one of the deals they tried to make with us was we would have a partner of a Japanese engineering firm, who would sit by our side and learn how to do what we were doing. It was pretty clear to me that it wouldn't be very long before they wouldn't hire me again. These are facts of life.

I don't know whether that helps or not.

Mr. VALENTINE. Yes, sir, it does.

Mr. Henry, you mentioned some possible change in tort law. What did you have in mind specifically?

Mr. HENRY. Something has to be done to put a cap or a ceiling on excessive judgments and awards that have been made. It's impeding introduction of products that could be an advancement for technology. But with the "deep pocket syndrome," the manufacturer who invents a product is virtually being held totally responsible.

If a contractor or subcontractor doesn't properly install the product, he will not be sued. No one is going to get a multi-million dollar judgment from a small builder. The legal system in this country has allowed plaintiffs to go to the person who has the most money and then holding him totally responsible, but I think there are some parallels that can be drawn with the recent awards with asbestos and what it's done to a couple of companies in that industry. We may see another problem surfacing in the problem of lead-based paint, which is now becoming an issue. Years after we have stopped manufacturing certain products we have litigation that will virtually bankrupt our publicly-held companies. Somebody has to put a ceiling on this and stop letting the attorneys dictate what we are doing.

A lot of competent people are not serving as directors on publicly-held companies because they can't get liability insurance coverage. It's a risk they will assume being sued as individuals as well as a group of directors.

Mr. VALENTINE. Yes. I don't want to make the situation more gloomy than it is, but you know, with all of the wonderful things about this country, and all of the problems, one of the biggest problems we might have is with the judicial system, not only problems that you're talking about, but you know, we sue somebody at the drop of a hat, and that's what we see, so many of us. I'm talking as a—in my other life I was a country lawyer for about 30 years, and it's—we've—and if you think we have problems with the system at that level, you should see it down at the bottom level of the criminal justice system, where continuances and deny justice and due process to many people who don't have any—really don't have the recourse that you gentlemen would have and so on.

Mr. Roe, I—well, you mentioned the federal and state governments that, in your opinion—we understood you to say the federal and state governments deter technology innovation. I don't want to pursue that any more here necessarily but if you could have someone in your firm send us some examples of that, it would be very helpful.

Do you have anything?

Mr. NAGLE. Mr. Henry?

Mr. VALENTINE. Mr. Nagle?

Mr. NAGLE. Mr. Henry, I was glad you said that. Now we know. I came in this morning and picked up Mr. Anderson's column and found out that the problem with Congress is we're all lawyers, and now I find out that the problem in the building construction trade is because we're all lawyers. I didn't know I had as much power, but it's nice to know that all we have to do is eliminate the lawyers and we've got the country's problems solved. [Laughter.]

But there's two areas of concern that I have——

Mr. VALENTINE. That's just some of the lawyers. Not you or me.

Mr. NAGLE. But I always seem to be around when they say it, though.

I'd just like to ask you a couple of questions, and understand it's coming from a lawyer, so, you know, probably they won't be comprehensible and I won't understand the answer, but the lag time on—in your industry between basic research and applied, I believe in your testimony, something like 10 to 15 years, if I read that—think I read that correctly——

Mr. HENRY. Yes, sir.

Mr. NAGLE. And one of the things where we're short, I think, against the Japanese is I think in our capacity to take basic research and move it to the applied field. What can we do to eliminate or decrease that gap that you find within your industry?

Mr. HENRY. One area that has been suggested is getting new technology approved through our total process in this country. We have three model code organizations plus KABO, which has a national evaluation system. When a products manufacturer goes to the code organization, the manufacturer gets a compliance or an evaluation report which says that the product or material meets the model codes and can then be adopted anywhere the code system is operating. We have three uniform codes throughout the country. Normally, the process for a compliance or evaluation report is quite quick, and there's no problem at that level. Where we do run into a snag is at state and local governments if they do not accept the uniform code without any changes. That's where we've had a problem. Certain major cities have their own code or do not accept the uniform code. As a result one has to get another compliance. The approval falls down to the local building official making the decision, rather than as is being done in Europe at a national level.

Mr. NAGLE. What else? If we just had a uniform code, that would solve the problem, the lag time problem?

Mr. HENRY. It's more than that. It really comes down to the local jurisdiction saying "yes, we accept that." In Europe, builders are liable generally for 10 years. As a result, there's more willingness to take new innovation and new products and put it into the marketplace, see if it works, and if it does, then accept that as being a standard.

Mr. NAGLE. Well, that does tie into my second question, but let me ask Mr. Roe or Mr.——

Mr. HENRY. Well, Mr. Miller, I think, has been doing more work in this area than we have.

Mr. MILLER. I think a lot of the problem comes down to communications, like everything we do. We have a problem——

Mr. NAGLE. 10 to 15 years?

Mr. MILLER. Well, part of the problem is people want to do things the old way. We need to develop a system of education and information and an ability to get technology transfer down into the trenches. We have got to make the small builder comfortable with the ideas that are new and innovative.

In order to do that, he needs to think he's not going to get sued for everything he's going to do, and that's the point that Rene brought up. Maybe we need a central clearinghouse or we need to establish some sort of an authoritarian committee, the appropriate people that says okay, these new technologies are all right, and together with that goes an insurance program that says you can bring it down to local levels and use it. Now that will give your local codes an out or a reason to accept new technologies.

Mr. NAGLE. But the reason I asked that question is because what you are telling me within your industry is not isolated to your group. I mean there is a real gap in this country between basic similar research and applied research. It's not just in your universe, it's in the country.

Mr. MILLER. Absolutely.

Mr. NAGLE. We don't get—we may find—one of the reasons patents are granted to foreigners is because they're better at applied than what we are, and my question is how do we address that problem. I mean okay, we get rid of the lawyers and we get a uniform standard. Now is that going to solve the problem? I don't think so.

Mr. MILLER. One of the major goals of the research committee for housing now is to establish the research agenda. That process we are starting, but we have just approved a study to address technology assessment, where are we today, what's the state of the art of the things that can be used? Then we turn that around and we start working on approvals, whether it's through the code process or establishing new state codes, some way we have to get some kind of uniformity. I'm not saying it needs to be national, but at least on a state basis, so that the local codes can accept new technologies.

In order to be competitive and in order to meet these foreign market competition forces, we have got to be able to turn the early adapters into a driving force.

Now the typical technology turn-around time is about 10 years in our industry. If we can move that up to eight years, the return on the investment is 100 percent more than it is now. We can do that by education and technology transfer. That's where the public and the private sector can collaborate to adopt programs that educate the people.

Mr. NAGLE. Let me explore that, if I can, while you're on that point. Is there a system within your industry—I appreciate the problem. You've got a lot of individual entrepreneurs, nothing wrong with that, that's good, that's what this country is about, people making their own way. But is there within your industry a system of check-off to fund industry research? I mean cattlemen, for example, check off to fund beef expansion, and soybean growers

check off to take a portion of their check and give it back for research. Does your industry have a similar type of operation?

Mr. MILLER. Our greatest resource is the National Research Center, which is the National Research Foundation for Housing, a Division of National Association of Homebuilders. That's been around for about 30 years, and it's just now really coming into its own to where with our new research agenda, we should be able to be known as the standard-setter for the housing industry.

Mr. NAGLE. What about the rest of construction, commercial? Mr. Henry?

Mr. HENRY. Most of this comes from the materials manufacturer or associations such as the American Plywood Association, the National Forest Products Association and Architectural Aluminum Manufacturers Association for example. Their members contribute based on any number of formulas, not necessarily a check-off; but call it whatever you would, each have allocated certain percentage of funding for the association going into research.

Ninety-three percent of the private sector funding for research comes from the building materials manufacturers. Their associations and organizations make that possible.

Mr. NAGLE. So go back to my threshold question, let me ask Mr. Roe and Mr. Adams if you have any thoughts on it. How do we narrow, cut the gap, other than the suggestions that have been made? How do we narrow or cut the gap between the basic research industry and bringing it out into—bringing it out into the field, putting it—getting it into the marketplace?

Mr. ADAMS. I'll start and turn it over to Mr. Roe.

I think the problem is more basic than that, that there is very, very little money being spent in basic research.

Mr. ROE. This is a complex question, and I'm sure you know it. One of the problems you have is exactly the one that Mr. Adams just pointed out. There is no existing system by which people in our industry can set aside money for research. One of the closest things in the area that I work a great deal in, which is the nuclear power, the Electric Power Research Institute, which was put together by the utilities and other people to look at their research problems, but their research problems are more with materials and with equipment than with the construction side. They made an attempt a little while ago to try and do something with that, and nothing much came of it, because it didn't have the priority or the support financially that would come from manufacturers, et cetera. So that's one of the problems.

The other problem is that the research and the fruits of the research simply don't exist, and you cannot apply research that has not been done, and that—so one of the first things that we have to do is to get research going.

Now we have other problems that would be something we'd have to solve, even if the research were there, and even if the money were there. One of the people on the panel before mentioned that on almost any project, you put together teams of people that may never have worked together before, and perhaps may never work together again. This is particularly true of the construction staffs in the field themselves. They come from many parts of the country, they have a wide spectrum of education and experience, and so

they are indeed untrained in many ways. I think there is a big need in this country to do training of the work force that you have in these jobs to do something with the research that must come.

In other words, you have got to do something with the work force itself. I think the entrepreneurial drive of the industry in this business will do a great deal to disseminate research if it has been done.

Now some years ago in our company we set up a program to train workers in the nuclear industry on the construction side. We tried—we set up a program to train their supervisors, because they were in many cases well-meaning people that simply didn't have the background to supervise the construction of the day-to-day operations of a large complex highly technical program, and we found that there was great acceptance of that by the unions, and we found that in many, many cases our clients were willing to undertake it.

But that, I think, is the kind of thing we've got to do. We've got to start to try to train the supervisors, we've got to train the work staff, and we've got to get the research done so that we have something to apply.

Mr. NAGLE. Mr. Henry?

Mr. HENRY. Our building seismic safety council, which is a part of the National Institute of Building Sciences, has done a lot of work with FEMA, and we feel that more funds now need to be taken from the basic research into applied research and there's a far greater amount that's still being spent on theory rather than practicality. I would like to get those figures for you and submit them, because I think it's important that we start looking more at the applied research and in the field, particularly in the seismic studies area.

[Material referred to follows:]

Since its inception in 1979, the work of the Building Seismic Safety Council of the National Institute of Building Sciences, has involved many thousands of hours of voluntary contributions of effort and expertise from individuals who have sought little, if any, recognition for themselves of their services. Many of these individuals, however, are beginning to indicate that it is past time for the National Earthquake Hazards Reduction Program to significantly increase its emphasis on application activities that actually will make the occupants of this nation's buildings safer from collapse during earthquakes. Many have stated more and more often during recent years that the research conducted under the NEHRP has produced a wealth of technical knowledge that awaits only application to begin mitigating this nation's seismic hazard. Indeed, the research done during the past 10 years has brought us to the point at which we finally are able to act on the basis of sound technical data but act is what we must do if, in fact, earthquake hazards are to be reduced.

A review of NEHRP funding indicates that a total of approximately $619 million has been authorized over the past 10 years for programs to be carried out by the USGS, NSF, NBS and FEMA. That total breaks out approximately as follows: $334,300,000 was used by USGS, $251,700,000 was used by NSF, $4,122,000 was used by NBS, and $28,700,000 was used by FEMA.

According to best estimates, approximately 95% of the USGS and NSF funds were used for research activities and the remaining 5% of the USGS and NSF funds along with 100% of NBS and FEMA funds were used for application and program activities. Therefore, it appears that to date nearly 90% of the available funds has been devoted to research and that there has been little emphasis on applying what has been produced by this research. Now, however, it is essential to use this "research" to refine the basic "tools" it has given us, to develop any needed additional tools, and to encourage every community at risk from seismic hazards to use these tools. Our point is not that research should not be funded or that little will be gained from further research; this is not the case at all. Rather, what is needed is a

better balancing of funding between research and application and, perhaps, a better focusing of research of what those actually acting to reduce earthquake hazards need and want to know to do their job better.

Mr. NAGLE. Now let me go back, if I can, to the second half of that question, which you, Mr. Henry, started to address and that's simply this:

Recently we passed national utility standards, as a matter of fact, manufacturers of furniture and appliances in my district, and I thought that, you know, I'm not eager for more federal regulation or laws, and I think we've got enough of them. But I called and both companies want them. A man in Lennox, you know. I raised the question to maybe even think the unthinkable, we've gone to a uniform commercial code, so that your security laws are the same in every state. Is it time that we took that step to bring in a national standard for construction rather than allow this individual state-by-state jurisdiction impediment, innovation, technological improvement?

Mr. ROE. Mr. Nagle, the codes are not just by state, they are also by township.

Mr. NAGLE. I understand that. Years back, I was a city attorney, and we took the Uniform Building Electrical Code, and we had an electrician there that didn't like some of it, so we made some changes, and if you wanted to build something in Evansdale that involved electrical wiring, you had the Evansdale standard and then you had the national standard, and you had a state standard, and I think Dysart down the road did the same thing.

But should we then take the step of uniform national standards within your industry, gentlemen? I'm asking.

Mr. MILLER. Our approach has been to encourage state legislation on the state level which does allow for some local variable conditions.

However, I think there is a need for some sort of a national committee on technological innovations that could be—have a stamp of approval from a respected body that could then be eligible for insurance in the local jurisdiction so that the codes, even though they may not facilitate the use of new technologies, could have a way for a trial period so that the new things could be put into place, but with some assurance that this has gone through testing and come from the approval of a nationally recognized commission or committee.

Mr. NAGLE. Well, I think that—and I haven't thought about this deeply, I admit that, but I think that you're kind of backing up from biting the bullet. I think that ultimately we are going to have to have a national standard, and I think maybe it can be administered by the states, maybe it can be administered by localities, but I think if you're going to move to a system that will insulate you from lawsuits because you complied with the national standards, if you are going to move technological innovation into—and bring it—match it as closely as possible, you are going to have to do that on a national basis. Am I wrong?

Mr. HENRY. I don't believe so, sir. We do have a preemptive national code now for HUD that covers manufactured housing, i.e., mobile homes. There has been discussion in Congressman Gonzales' committee on H.R. 4 on the pros and cons of adding all factory-

built housing to of a preemptive national code, that area. As a result, our Institute is having a forum in Orlando on Monday and Indianapolis next Wednesday and then in California on June 17 to bring together all sectors of the industry to discuss the regulatory issues, the pros and cons of a preemptive federal standard versus voluntarily accepted standards, as is now the case with the modular and panelized industries.

The real underlying problem right now has not been focused on the uniform codes, which are very close in relationship to one another, but how they are administered at the local level That's where it gets out of hand. Builders can have numerous jurisdictions within a county and even more so within a state.

There is an effort being made through the CABS one and two-family housing code. We have been involved with discussions to have if voluntarily accepted on a statewide basis. That would be a major step in the right direction We'd rather see it done on a voluntary basis, rather than mandated as a federal preemptive code. The HUD code has been twisted and discriminated against by zoning. We will be looking into that. We heard one isolated case in the county where a manufactured unit needs the HUD code standard but does not have the local jurisdiction of the statewide code, even though the federal is preemptive, the local zoning is one unit per 10 acres. There are other ways that cities have fought back, even against a federal code. We are trying to uncover abuses like that.

Mr. NAGLE. Yes, and I understand that. And there is also the other side of it, where I have seen situations on a Section 8 housing where the HUD standard is just not related to the real world. I mean they are too stringent, requiring construction costs that frankly weren't necessary, but the standard required it, so therefore you had to do it. And I've seen it coming from the other side.

I don't mean to say that I am going to introduce legislation tomorrow to put a uniform standard in, but I do think that that's one of your problems. I think we have to address it, and local compliance or local cooperation, state cooperation, would be far better.

Mr. Roe, you raised an interesting question. The Administration has proposed the virtual elimination of all federal assistance for vocational education, except for those areas that are directly tied to displaced workers by foreign competition. It is part of their new competitive package. Should we take the Administration's suggestion?

Mr. ROE. Well, I think you've got the problem I have with my own personal budget. There are many things I would like to do that I don't have the money to do. I think the job of Congress is to decide what the priorities are. I think we need to train people. I think that we need to do anything we can to make that possible, but I would hesitate to decide where it should fit in the national priority budget. I don't know that that's an answer that you like very much, and I am not trying to be difficult, but it's just something——

Mr. NAGLE. Well, that's the same problem we struggle with up here.

Mr. ROE. I don't know how to set that priority. I do know it's something that I think would be good.

Mr. NAGLE. Okay. Anybody else want to address that? Mr. Miller?

Mr. MILLER. A little earlier I mentioned one of the solutions is the Job Corps which is sponsored by the National Association of Homebuilders. It doesn't get into the levels that Mr. Roe is referring to, and I think that program could be expanded. We made a decision to sponsor that effort, and that is federally funded. There is an opportunity to introduce the new technologies through the Job Corps, and you are taking kids who were not productive, maybe had some sort of a problem, a burden on society, and turning them into crafts people, and they earn money and pay taxes. That program could perhaps be expanded a little bit and raised a level to supervisory personnel and take a look at that. The system may already be in place, just need a little looking at.

Mr. NAGLE. Let me apologize for being late. I was at another hearing on the Farm Credit System, but frankly I wasn't aware of your industry's problems and your testimony and that that I read last night and before I came today has been enlightening, and I frankly have been educated today by your answers and by your courtesy, and I thank you.

Mr. VALENTINE. Thank you, sir. I just want to mention one matter, and then we will wrap this thing up. I would like to say to you gentlemen that we will reserve the right to submit written questions and to hope that we can—the staff will elicit some specific answers to those questions that have been based on what we heard here today, and perhaps other matters.

Mr. Henry, in your prepared testimony, you said this, that Yugoslavia recently won a competition to provide a steam generating plant for the U.S. Naval Base at Norfolk, Virginia with a bid that was 50 percent lower than the next bid. Do you know whether that has occurred with any degree of frequency at other Naval—other military installations in this country?

Mr. HENRY. Not that we have been able to track. That was one isolated example that we found I think it certainly points out the need that—they were able to come in with a much lower bid because of certain parts and equipment and subsidy from their own government. I do know that a Japanese contracting firm won a major nuclear project in Virginia, which was announced just a month or so ago.

Mr. VALENTINE. So we've got then—they won that competition, they got the bid. When was this? How long ago?

Mr. HENRY. We'll have to get it specifically. We have the newspaper clippings, and we will follow up on that for you.

[Information to be furnished follows:]

NORFOLK VIRGINIAN PILOT

Navy stumped over Yugoslav contract bid

By JACK DORSEY
Staff writer

NORFOLK — The Navy "is up a creek" over a contract that would allow a contractor from communist Yugoslavia to build a steam-generating plant at the Norfolk Naval Station, a Virginia congressman said Friday.

Navy officials agreed privately that there probably is little they can do legally to prevent the project despite security concerns.

"There is no reason not to award this contract. It is perfectly legal. There is nothing wrong with it," said a Navy official who asked anonymity. "But, obviously, we have some concerns."

The Navy is concerned about the potential national security risks if Yugoslavs build and possibly operate the plant in the largest Navy complex in the United States, said 4th District Rep. Norman Sisisky, a Democrat.

"The Navy is really up a creek," said Sisisky, whose district includes Portsmouth, Chesapeake and Suffolk. "They're in a trap, by law."

The company, which the Navy would not identify, bid 50 percent lower than the next lowest bidder to supply 340,000 pounds of steam per hour for heat and other energy uses, officials said.

The possibility that a communist nation could perform construction work on a military facility as sensitive as the naval station infuriated one union official.

"I don't understand why these communists need to build all these missiles and such," said Thomas E. Rinehart, chairman of the Tidewater Virginia Federal Employees Metal Trades Council. "They can just low-bid us and come in and we'll just sell them our national defense."

There is precedent for allowing a contractor from a communist nation to work on a U.S. military facility.

On the island of Guam, a U.S. territory in the Marianas chain, a Chinese contractor was the successful bidder a few years ago to replace wooden telephone poles with concrete ones, said Marge Holtz, spokeswoman for the Navy Facilities Engineering Command in Washington D.C.

Although the Chinese firm eventually defaulted on the contract when it became unprofitable to continue, the Navy had no problem awarding the company the contract, Holtz said. "It was a legitimate bid, and it did not involve working in a security area." The work was in a Navy housing project.

The Norfolk plant, which would replace an antiquated one, would be on Navy property along Taussig Boulevard across from the Naval Dental Clinic.

The Navy requested bids a year ago for the project, which would generate steam to heat buildings and provide energy to the base piers for ships.

In the fiscal 1988 military construction budget, the Navy allocated $27.7 million to expand its steam plant at the base and $1.5 million for a 12-inch-diameter steam line.

Members of the House Armed Services seapower subcommittee were informed of the issue Thursday by Everett Pyatt, assistant secretary of the Navy for shipbuilding and logistics.

Pyatt — admitting to the congressmen, "I don't know what to do" — has asked for their guidance. The Navy has put the contract on hold for the next 30 days while it consults with Congress, he said.

Rinehart said his union, which represents Navy public works employees at the base, is complaining to area congressmen.

"We are definitely opposed to having any communist country involved in our national defense," he said, "especially when it comes to something that would affect the readiness of this installation as much as steam would."

Navy ships hook up to "hotel services" when in port, Rinehart said. "All they have to do is start fires in their own boilers to get out of here. If Yugoslavia decided it wanted to shut us down for a week, every ship in our fleet would be in cold irons in a matter of 24 hours. Then it would take three to five days to get them up and out of here," he said.

"If there's no law against it, there ought to be," Rinehart said.

Rep. Owen B. Pickett, the first-term Democrat who represents Norfolk and Virginia Beach, said neither the Navy nor members of Congress know for sure whether Yugoslav workers would build the plant, run it or maintain and repair it.

The Navy did not foresee the problem, so the request for bids did not detail all of the terms under which the Navy would buy the steam, he said.

"This is part of what we are trying to determine now," Pickett said. "We are trying to get some more specifics about the equipment that will be installed, whether foreign personnel will have to maintain it, and whether there will be difficulty with the continuity of service."

All civilian workers allowed on the naval station are required to have security clearance, and merchant vessels from communist countries are forbidden to make port in Norfolk and Portsmouth.

Yugoslavia has ties to the Soviet Union but is not part of the Soviet bloc.

The Norfolk Naval Base, the largest in the world, is home to 125 ships and 110,000 sailors and Marines.

"The Navy is buying steam, not the plant," said Holtz, the Navy spokeswoman. It is a third-party financed plant. The Navy provides the property. A private-sector contractor comes aboard and builds on the property and operates the plant. The Navy buys from the contractor. In this particular case it's steam. The Navy does not operate the plant," she said.

Congress is very much in favor of third party financing, particularly for steam and energy plants, because it puts money back into the economy, Holtz said.

The low bid saves the government a lot of money, Holtz said. "It's a significant savings," she said, although she declined to say how much, noting that it would be inappropriate to release such figures until the contract is accepted.

The plant also would eventually employ Americans, Holtz said, and become part of the Hampton Roads economy.

Mr. VALENTINE. But it's—as far as you know, it either has been completed or it's in construction now?

Mr. HENRY. The award was made, I believe, January or February. It caused quite a stir, particularly the people at Norfolk Naval Base were concerned about security clearances.

Mr. VALENTINE. I was just going to say, so then we either now have had or do have a Yugoslavian contingent that's down there crawling all over that Naval base building what they say is a steam generating plant. Maybe bugging it and all that stuff.

Mr. HENRY. Well, there was a reference made by the commander of the fleet that if the system went down, it might take five or six days for our fleet to be operational.

Mr. VALENTINE. Okay. Well, we are a great free trading company—country; you know, do whatever you want to, to us. That's what it seems like a lot of times, isn't it? Yet I remember one parting shot that—this doesn't have anything to do with any of you guys and any of the businesses that you represent now or have in the past, but I remember well about 15, 20 years ago, when I decided that I would like to drive a small economical automobile, and I would go to my friend the dealer, and he'd laugh at me. You know, he'd always send me to that big car, and I—and I couldn't buy an American made automobile that met the needs that I yearned for. I wanted a small, well built, attractive, economical, compact car, and every time I tried to buy one made in this country, they laughed at me. And somebody else filled the need.

Thank you all very much for—do you have anything else?

Thank you all for coming.

[Whereupon, at 12:12 o'clock p.m., the subcommittee was adjourned.]

APPENDIX

Construction Productivity

Proposed Actions by the Federal Government to Promote Increased Efficiency in Construction

Committee on Construction Productivity
Building Research Board
Commission on Engineering and Technical Systems
National Research Council

As we seek to best use our national resources and to maintain our international competitiveness, the productivity of the American economy is of major concern to all Americans.

Building--the planning, design and construction of new facilities as well as the ongoing repair and rehabilitation of existing facilities--is especially important. We invest over $300 billion in newly-constructed homes, nonresidential buildings of all kinds, industrial and utility plants, highways and other transportation facilities each year. The productivity of the construction industry directly influences the productivity of every segment of the American economy.

A visit to any construction site, however, will confirm that building is a complex, slow and stubborn business. The products of the construction industry are bulky, complex and expensive. Most are one-of-a-kind designs and, in most cases, the factors of production must be brought to and assembled at a unique site. For each project a temporary multi-organization of people and firms who have different interests and values, who have not worked together, and may not work together again, is brought into being. It is no wonder that there have been so many allegations of low productivity in this critically important industry.

With an estimated $50 billion annual outlay in construction-related expenditures, there is no larger stake-holder in this problem than the federal government itself. Given this reality, the agencies that sponsor the Federal Construction Council asked the Building Research Board to determine what they can do, if anything, to stimulate increased productivity. This is the report of the BRB study committee.

Our charge led us directly into a problem of measurement. As important as construction productivity may be, establishing measures for it has been vexacious. There is not agreement on how best to measure the inputs and the outputs, and easily-understood single-factor measures are inappropriate. The federal government's own measure, which is flawed and no longer published, suggests dramatic decreases in construction productivity over the past 20 years. Some analysts suggest that the situation is not as bad as that. Our conclusion: Depending on who you wish to believe, productivity is poor, or at best, not

improving. By any measure it is trailing productivity gains in other sectors of the economy and, given our annual national investment in building, that is a problem.

Solutions? There are no easy ones. Given the nature of the construction process and the lack of concentration in the building industry, we sought an underlying issue which, when substantively addressed, might yield the hope of improvement for all construction projects. Since investments in research and development are generally considered to be effective in improving productivity, we have focused on R&D in all of its forms--from basic research to dissemination and demonstration of what is already known--as a strategy for improving construction productivity in the United States.

In this report, we examine who undertakes construction research in the United States, for what reasons and at what levels of investment. We look at how it compares with R&D investments in other industries and, briefly, with construction R&D in other countries. We critically review past efforts by the federal government to stimulate research or innovation, both in building and in other areas. Finally, we suggest a strategy for significantly increasing the level of research and development committed to construction in general and to construction productivity specifically.

This was a short study done without benefit of vast resources. The study committee acknowledges the contributions made by our federal agency liaison members and most especially by Henry Borger of the BRB staff.

David S. Haviland
Committee Chairman

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EXECUTIVE SUMMARY

During the past 2 decades many individuals and organizations have expressed alarm about an apparent decline in the productivity of the U.S. construction industry, and there have been numerous calls for the federal government to take action to reverse the trend.

The federal agencies that sponsor the Federal Construction Council asked the Building Research Board to assemble a committee of knowledgeable individuals to assess the current state of technology and research related to construction productivity in the United States and to explore the possible roles of federal construction agencies in fostering research and the development of new construction techniques. The committee was formed and conducted its investigation during calendar year 1985. This report presents the results of the committee's work.

The committee affirmed that the federal government has a legitimate interest in the health and productivity of the construction industry, both because the industry is a huge and vitally important element of the national economy (it accounts for more than 8 percent of the gross national product and has a major impact on most other elements of the economy) and because the federal government funds a significant percentage of all U.S. construction work. The committee also affirmed, however, that the construction industry is highly decentralized and complex and is not easily influenced by federal action.

On the basis of a review of the literature and its own analysis, the committee found that it is difficult to show conclusively that construction productivity has actually decreased in recent years or, if it has decreased, to show the magnitude of the decrease. However, most evidence suggests that even if construction productivity has not actually decreased, it probably has not increased very much either. Futhermore, it is almost certain that productivity growth in construction has been slower than in other industries in the United States. The committee concluded that although there is a need for more comprehensive and accurate measurement of construction productivity, efforts to improve productivity need not be deferred until more accurate estimates are available. There is already sufficient evidence that a productivity problem exists to justify action.

Because it has been clearly demonstrated that, as a general rule, productivity is increased through investments in R&D, one of the reasons often given for the current productivity problems of the construction industry is insufficient R&D.* On the basis of its analysis, the committee determined that:

- The total annual investment in R&D by all elements of the construction community probably amounts to about 0.39 percent of the annual value of construction put in place. Manufacturers of construction materials, products, and equipment probably account for almost 69 percent of all construction-related R&D in the United States, government agencies for about 18 percent, contractors for about 4 percent, and all other elements of the building community (e.g., labor unions, architects, and various engineering disciplines) for about 9 percent.
- The U.S. construction community, including users, manufacturers, contractors, government agencies, and others, probably invest proportionally less in R&D than other U.S. industries and also less than the construction industries in some foreign countries, notably Japan.
- The federal government invests less in construction R&D than in R&D in other fields.

Based on the lack of increase in U.S. construction productivity over the past 20 years and the low rate of investment in construction-related R&D, the committee concluded that construction-related R&D has been inadequate in the United States and needs to be increased. Because of the complexity and diversity of the construction industry, it is impossible to determine precisely how much of an increase in R&D is needed. It is apparent, however, that the current level of investments in R&D is sufficiently low that the amount of R&D could easily be increased several fold before the point of diminishing returns is reached.

The committee also concluded that there is little reason to hope that the needed increase will come from the private sector. Although the existence of a construction-productivity problem has been recognized and discussed for many years, the amount spent on R&D by private

*Various economic and sociological factors that are outside of the control of the construction community also have been cited as reasons for the productivity problems of the construction industry (e.g., fluctuations in interest rates, a shift in the nature of the output of the construction industry, and a drop in the average age of construction workers). While such factors probably have contributed to the productivity problem, the committee has focused on the technical and managerial aspects of the construction process itself (i.e., the planning, design, and construction of buildings and similar facilities) because that was its charge and out of conviction that problems with the construction process have been the major cause of the productivity problems, though possibly not the only cause.

members of the construction community (except manufacturers) has remained low. It seems unlikely that the factors that have caused this situation (e.g., the attitudes of those involved and/or the structure of the industry) would change now. Therefore, if there is to be an increase in construction R&D, some direct action by the federal government will be required.

As part of its review of construction-related R&D in the United States, the committee explored whether the current supply of researchers would permit an expanded R&D effort. The committee concluded that while an increase in spending for construction-related R&D might produce a temporary shortage of researchers in various fields who are familiar with the construction process, the shortage would not persist for very long.

The committee next reviewed the history of previous government efforts to promote technological innovation to determine what type of federal construction R&D program (if any) might succeed. The committee concluded that with currently available statistics and analytical tools, it is impossible to determine in terms of macro-economics how federal R&D programs affect the overall economy. Most economists seem to believe intuitively that such programs are beneficial; however, they cannot prove it. Most also believe that federal R&D expenditures do not cause a decrease in private R&D investments.

The committee also found that the results of previous and ongoing federal R&D programs are varied. Some programs have been highly successful, others have failed. Whether a program succeeds or fails seems to depend more on nontechnical considerations than technical ones. Where a federal construction-related R&D program is carefully crafted, it has a good chance of succeeding.

The keys to a successful federal R&D program, the committee concluded, are the following:

- Involve representatives of all segments of the building community in the process of formulating the program, and design the program to address a broad spectrum of needs. For example, the concerns of federal agencies that procure buildings as well as those of agencies that are interested in broader issues should be recognized.
- Concentrate on generic (non-proprietary) problems, opportunities, and issues; avoid involvement in the design, development, manufacturing, or marketing of proprietary products or concepts.
- Try to get a long term commitment to the program from Congress.
- Design the program to generate numerous small payoffs over an indefinite period of time; do not promise big results quickly.
- Design the program to cover the full spectrum of R&D projects, from the discovery of new basic knowledge to the development of better methods of disseminating known technology.
- Design the program to permit researchers and research organizations from various segments of the industry to participate.

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- Include a mechanism for promoting continuous two-way communications between users of technology (e.g., owners, contractors, designers) and researchers. R&D is of little value if it does not address real problems and important issues and if the results are not widely disseminated.
- Keep the size of the program large enough to ensure that many members of the building community can be involved and that the results of R&D will have widespread inpact, but not so large that it becomes a target for budget cutting.
- Find a mechanism for funding the program that helps give it stability and continuity.

The committee also concluded that it would be unrealistic to expect operational agencies to take the lead in performing or funding R&D of a generic nature. Agencies are under almost constant pressure to reduce budgets and expenditures, and most are unwilling to try to defend requests for funds that are not clearly related to their missions. Therefore, the committee concluded that the initiative would have to come from the Congress, and toward this end it offered the following recommendations:

1. The Congress should formally acknowledge the need for federal leadership in conducting, funding, and coordinating general construction-related R&D, just as it has in agriculture, medicine, transportation, and many other fields. This acknowledged leadership should be reflected in a federal program.
2. In order to ensure the stability of the program, the Congress should consider methods of funding a strong federal R&D program that would provide stability and continuity. Numerous options are available. Congress might consider, for example, providing multi-year authorization and appropriation for the program, establishing a program trust fund of some type, or funding the program through an automatic surcharge on all federal construction appropriations--like the approach that has been used for many years to fund highway research and planning.*
3. In order to ensure that a broad spectrum of construction R&D needs are met, the Congress should provide for the distribution of program funds to the various federal agencies that have construction-related responsibilities; for example, some funds could be allocated to

*In FY 1984 the federal government spent a total of almost $44 billion on construction (see Chapter 3). If, for example, a 1.0 percent surcharge had been added to each construction appropriation that year, approximately $440 million would have been generated for construction related research. Inasmuch as federal agencies actually spent about $220 million in FY 1984 on construction R&D, the 1.0 percent surcharge would have increased the FY 1984 budget by only $220 million.

the agencies that are responsible for procuring federal facilities for R&D on the design and construction of such facilities; some funds could be allocated to agencies like the National Bureau of Standards and the National Science Foundation for generic R&D for the entire construction community; and some funds could be allocated to information-generating agencies like the Bureau of the Census and the Bureau of Labor Statistics for the development and publication of more accurate construction statistics.

4. In formulating the program, the Congress should provide a mechanism to ensure that the construction R&D activities of the various federal agencies are coordinated and that information and technology produced through such activities are widely disseminated. To accomplish this, the Congress might consider giving a particular agency overall responsibility for managing the program and distributing R&D funds to other agencies. Alternatively, Congress might permit the various agencies to manage their own R&D programs, but require them to participate in a cooperative, coordination body (either public or private) that would do for construction R&D what the National Research Council's Transportation Research Board has done for highway research for many years. (See Appendix C for a discussion of federal highway research programs and the Transportation Research Board's role in those programs.)

2

INTRODUCTION

For more than a decade, various individuals and organizations have expressed concern and in some cases alarm about declining productivity in the U.S. construction industry. The Business Roundtable (1983)* described the situation as follows:

> Since the closing years of the sixties, productivity in construction has been declining at a rate many industry leaders find appalling. The figures should not be regarded as precise because of statistical deficiencies in the data on which they are based... but they all contain the same disturbing message: A large and increasing gap has opened between the performance of construction and that of U.S. industry as a whole. In 1981, for example, the Commerce Department reported that productivity in new construction put in place had dropped from an index number of 100 in 1972 to an index of 82.9 in 1979--a debilitating decline of nearly 20 percent. The Houston-based American Productivity Center, measuring labor productivity in 11 large sectors of the U.S. economy over a span of three decades, found construction to be the most laggard performer by a wide margin. Since 1965, according to the Center, construction has been the only industry with consistently negative productivity growth. The average annual rate of change was minus 0.9 percent from 1965 to 1973, then dropped 3 percent a year from 1973 to 1979 and an alarming 8 percent a year in 1979-80.

As a reflection of its concern about declining construction productivity, the Business Roundtable published a series of 23 detailed

*The Business Roundtable is a New York City based association in which the chief executive officers of some 200 major corporations meet to address a wide variety of public issues. It began in 1969 as The Construction Users Anti-Inflation Roundtable.

reports (plus two summary reports) presenting 223 specific recommendations for improving the performance of the construction industry--the majority of which were directed entirely or partially at owners (the consumers of the construction industry).

Concern about low construction productivity is not a recent development. It was one of the reasons offered by the Building Research Advisory Board in 1962 in support of a recommended expansion of the building research program of the National Bureau of Standards.

Subsequently, concern about low construction industry productivity was expressed at a number of conferences, including a joint conference of the National Commission on Productivity and the Construction Industry Collective Bargaining Commission in 1972 (National Commission on Productivity, 1972); a conference sponsored by the Stanford Construction Institute in 1975 (Paulson, 1975); a National Research Council (NRC) conference in 1979 (Building Research Advisory Board, 1980); a conference at the National Bureau of Standards in 1981 (Center for Building Technology, 1981); a workshop sponsored by the American Society of Civil Engineers in 1983 (Steering Committee on Civil Engineering Productivity, 1983); and a workshop sponsored by the National Science Foundation in 1984 (Ashley and Tucker, 1984). Numerous recommendations for improving productivity in the construction industry also were made at the conferences.

One way to improve construction productivity mentioned in many of the documents cited above is through increased research and development (R&D). Those recommending more R&D have usually justified it on the grounds that the construction industry currently spends very little on R&D by almost any standard: total dollars, as a percentage of construction expenditures, or when compared to other industries. Among the reasons that have been given for this situation are the fragmented/decentralized nature of the building industry and the uneven demand for construction services. However, it is often asserted that the construction industry will not significantly increase its investment in R&D without some special incentive. The Business Roundtable (1982b) was so skeptical of the industry's willingness to undertake a significant amount of R&D that it recommended the establishment of a new owner-funded R&D organization.

The federal agencies that sponsor the Federal Construction Council (FCC)* have participated in many of the recent conferences and studies on construction productivity, frequently concurring with the resulting conclusions and recommendations. Nevertheless, most of the agencies have hesitated to undertake or fund research aimed at improving construction productivity for several reasons: concern that such research

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*Department of the Air Force; Department of the Army; Department of Energy; Department of the Navy; Department of State; General Services Administration; National Aeronautics and Space Administration; National Bureau of Standards; National Endowment for the Arts; National Science Foundation; Public Health Service; U.S. Postal Service; Veterans Administration.

would be inappropriate because it is not directly related to the agency's mission; uncertainty about what kind of research is needed; and apprehension that government involvement would be resented by the construction industry. However because the agencies that sponsor the FCC are either construction-industry consumers or sponsors of construction-related research, they feel an obligation to assist the construction industry if their assistance is needed and wanted--particularly if by doing so they can help the government get more construction for the dollar. Thus, the agency sponsors of the FCC requested that the Building Research Board (BRB) of the NRC form a committee to undertake a study of the matter, with the following objectives:

- To assess the current state of technology and research related to construction productivity in the United States.
- To explore the possible roles of federal construction agencies in fostering research and the development of new construction techniques.

STUDY METHODS

To carry out the study, the BRB appointed an advisory committee with expertise in the organization and operation of the construction industry, construction productivity, and federal and private R&D programs. The committee's membership included representatives from the industry (builders, organized labor, construction management consultants), from academic institutions (representing economics, construction, and architecture), and liaison members from the sponsoring federal agencies.

The committee was asked to complete its study within 9 months. To meet this tight schedule, the committee adopted a number of clear boundaries for its work (see "Scope and Focus of The Study" below) and proceeded at a fast pace. Consequently, the committee could not thoroughly study some aspects of the problem.

The committee met four times in the course of the study. It reviewed and analyzed the current situation in the U.S. construction industry, including the size and nature of the industry, its productivity and technological sophistication, and the amount of research and development performed by and for the industry. It also received briefings on the nature and status of the design and construction research programs of various federal agencies and on related studies carried out by other NRC committees. Finally, the committee discussed and recommended actions that the federal government might take to improve construction productivity. Individual committee members wrote or provided background material for various sections of the report. The complete report was reviewed and edited by the entire committee.

SCOPE AND FOCUS OF THE STUDY

Before beginning its work, the committee defined several key concepts that would provide necessary and appropriate boundaries to its broad study of construction technology and R&D in the United States.

Range of Construction Projects Considered

This study considers the full range of construction projects undertaken by and for federal construction agencies rather than focusing on one segment of the industry (e.g., residential buildings, commercial buildings, industrial buildings, road construction, or utility construction). The construction industry is often divided into such segments, for it involves various people, skills, organizations, technologies, contracting methods, financing arrangements, and regulatory mechanisms. However, because the predominant audience for this report is the federal government and since federal agencies collectively manage all types of construction projects, the committee decided to consider the whole range of construction projects.

Phases of the Construction Cycle Considered

Although this study focuses on the construction phase in the life of a facility, other phases in the life cycle also are considered. There are many phases in the life of a building or similar facility. They are conceived, planned, designed, and built; then they are used, operated, maintained, repaired, and renovated; and eventually they are demolished or replaced. Thus, in looking for productivity improvements in construction, all phases of the life cycle of facilities need to be considered. Indeed it can be argued that the most significant productivity gains often stem from efforts taken during the early phases of a project. Consequently, although this study is primarily concerned with construction productivity improvements--and especially R&D to improve productivity during construction--other phases of the process also have been considered to the extent that they directly affect the construction phase.

Aspects of Construction Considered

This study considers both the technical and nontechnical aspects of the construction process. Often, construction productivity is discussed from a narrow perspective, for example in terms of one of the following: the design of the facility, its component parts, the technology of construction, the management of the design and construction process, or legal considerations in construction. However, because the committee believes that construction productivity is affected by many factors simultaneously, it agreed that this study should not ignore any aspect

of the design and construction process. On the other hand, the committee did not focus on broad economic and sociological factors like fluctuations in the money supply and the average age of construction workers, which may affect construction productivity but are outside of the control of the construction community.

Nature of R&D Activities Considered

This study takes a broad view of research and development activity. Over the years there have been heated debates about the nature of the R&D process and the appropriate type of R&D activity. The committee takes the view that R&D is a broad activity that includes basic research (the discovery of new insights and concepts) and the demonstration, application, and dissemination of known technology.

3

SIZE AND NATURE OF THE U.S. CONSTRUCTION INDUSTRY

Construction productivity is or should be a matter of national concern by virtue of the size of the industry and its importance to the national economy. Because the industry is tremendously complex and diverse, however, efforts at the national level to influence its course may be hindered.

SIZE OF THE INDUSTRY

Defining and measuring the size of the construction industry is difficult because of its fragmented nature and because construction activities frequently overlap or can be included as part of another industry. For example, construction contracts frequently call for the installation of such items as carpeting, home appliances, production equipment, and telephone systems, which are not usually considered construction products and which could be installed independently of the construction process. The question arises: Should the purchase and installation costs of such items be included in construction industry statistics? There are countless interfaces like these between the construction industry and other industries that create statistical grey areas. The problem is complicated by the fact that national statistics on construction are based mainly on data from construction contracts, which vary widely in what they include. Consequently, experts often disagree about the size of the construction industry.

One measure of the size of the U.S. construction industry is the dollar value of construction work. The most widely used statistics on construction volume are those on the value of new construction put in place in the United States, which are developed by the Bureau of the Census of the U.S. Department of Commerce. Table 1 shows the value of new construction put in place in the United States in 1984 for various categories of facilities. Of the 1984 total of almost $313 billion, approximately $258 billion was private construction and $55 billion was public (federal, state, and local government) construction.

TABLE 1 Value of New Construction Put in Place in 1984 (millions of current dollars)

Type of Construction	Value
Private Construction	
Residential buildings:	
New housing units	114,620
Non housekeeping (e.g. hotels)	7,000
Additions and alterations	23,440
Total	145,059
Nonresidential buildings:	
Industrial	13,745
Office	25,940
Other commercial	22,167
Religious	2,132
Educational	1,411
Hospital and institutional	6,297
Miscellaneous	2,455
Total	74,147
Farm nonresidential	2,860
Public utilities:	
Telephone and telegraph	7,174
Railroads	3,671
Electric light and power	19,473
Gas	3,233
Petroleum pipelines	271
Total	33,822
All other private	1,912
Total, private construction	257,801
Public Construction	
Buildings:	
Housing and redevelopment	1,636
Industrial	1,828
Educational	5,557
Hospital	2,039
Other	6,822
Total	17,883
Highways and streets	16,294
Military facilities	2,839
Conservation and development	4,654
Sewer systems	6,241
Water supply facilities	2,621
Miscellaneous public	4,654
Total, public construction	55,186
Total, all construction	312,987

SOURCE: Bureau of the Census (1985).

The size of the construction industry also can be expressed as a percentage of the Gross National Product (GNP). Using the latest figures available from the Department of Commerce, the construction industry accounted for 8.1 percent of the GNP in 1983 and 8.5 percent in 1984.

Another measure of the size of the industry is employment. Data collected by the Bureau of Labor Statistics (BLS) (1985) show that employment in the U.S. construction industry in July 1985 was 4.99 million, which amounted to 4.6 percent of those employed in the United States. However, the BLS data only include people employed by construction companies; they do not include, for example, workers employed by manufacturers of building products, construction workers in non-construction companies (e.g., "force account" workers), or architects, engineers, and others employed by design firms. If these workers had been included, construction industry employment would probably be in proportion to the industry's share of the GNP; thus it would probably total more than 8 percent of the national work force--more than 8.6 million workers.

The Department of Commerce and BLS statistics cited here demonstrate conclusively that the construction industry is a huge and vitally important part of the U.S. economy. However, the industry may be even larger than the government statistics indicate. The Business Roundtable (1982d) believes that the Department of Commerce statistics understate the size of the construction industry by failing to include some projects or portions of projects, particularly industrial. Specifically, the Roundtable has presented evidence that the Department of Commerce statistics for 1979 understated industrial construction volume by almost 79 percent ($54 billion) and total construction volume by almost 24 percent ($71 billion).

NATURE OF THE INDUSTRY

The most notable characteristic of the U.S. construction industry is its diversity and decentralization, which some refer to as fragmentation. There are almost 1 million general and specialty contractors in construction, (Business Roundtable, 1983), over 50,000 architect and consulting engineering firms (American Business Lists, 1985), over 25,000 building material dealers (American Business Lists, 1985), 15 major building and construction unions with more than 7,000 U.S. locals (personal communications with the various unions, 1985), at least 180 construction-related trade associations (Columbia Books, 1984), and more than 10,000 building code jurisdictions (Council of American Building Officials, personal communication, 1985).

Elements of the Industry

The construction industry, like all large institutions, can be subdivided into parts, and there are various ways of doing so. As

discussed under "Size of the Industry," one method of subdivision is on the basis of the type of facility constructed: residential buildings, residential additions, industrial buildings, office buildings, religious buildings, educational buildings, warehouses, hospitals and other institutional buildings, farm construction, telephone and telegraph facilities, gas distribution systems, electric power systems, railroads, petroleum pipelines, highways and streets, military facilities, conservation and development projects, sewer systems, and water supply facilities.

Because of the decentralized nature of the industry, it is sometimes asserted that there is not a single U.S. construction industry but several separate industries, each organized to construct a particular type of facility. For example, a specialized group of contractors, architects, material suppliers, and developers finance, design, and construct most single family residences. Their methods, materials, and contractual arrangements are different from those used for other types of construction. The construction of highways and streets, certain types of industrial facilities, and some utility work usually is also handled by specialist groups.

Another way to subdivide the construction industry is by services performed in the construction process. These include services by developers and owners, architects, engineers of various kinds, general contractors and construction managers, specialty (sub-) contractors, material and product manufacturers, material and product dealers, construction equipment manufacturers, construction equipment dealers, construction workers, labor unions, and government regulatory bodies.

Occasionally, the construction industry is described in terms of the phases in the life cycle of a facility, for example, programming and planning, design, bidding, construction, operation and maintenance, and demolition. Or in some cases, the industry is subdivided on the basis of the construction techniques used (e.g., "stick" building, prefabrication, modular construction, curtain wall construction, systems building) or the structural materials used (e.g., brick, stone, reinforced concrete, steel, concrete blocks, bricks and blocks, and wood).

Size of Construction Firms

Although the construction industry is highly fragmented and composed of thousands of independent businesses, not all construction-related firms are small. In 1984, for example 210 U.S. construction companies had contracts totaling more than $100 million each, and 18 companies had contracts totaling more than $1 billion each, just for work in the United States (Engineering News Record, April 18, 1985). Furthermore, the largest 25 construction firms accounted for almost one third of all non residential construction. Some design firms (engineers and architects) also are quite large; 17 firms had billings totaling $100 million or more in 1984, and another 24 firms had billings totaling $50 million or more (Engineering News Record, May 16, 1985).

TABLE 2 Profiles of Typical Construction Projects

Craft	Buildings[a]	Light Industrial[b]	Heavy Industrial[c]	Power[d]
		Labor Shares (percent)		
Boilermakers	1	1	2	11
Carpenters	16	14	8	9
Cement finishers	7	4	2	1
Electricians	11	10	18	15
Equipment operators	4	5	5	7
Insulators	1	2	4	2
Instrument	1	3	5	1
Ironworkers	14	9	7	10
Masons	4	6	1	1
Millrights	1	3	4	3
Laborers/helpers	17	14	10	13
Painters	4	3	2	2
Pipefitters	9	14	22	18
Riggers	1	1	2	0
Roofers	2	3	1	1
Teamsters	1	3	2	2
Welders	1	2	4	1
Others	5	3	1	3
		Cost Distribution (percent)		
Civil				
Earthwork	4.8	4.3	3.3	6.2
Foundations	3.3	7.2	7.5	10.4
Structure	26.9	17.2	8.2	9.7
Enclosure skin	15.2	7.0	1.7	1.8
Interior finishing	11.6	8.5	1.6	2.2
Roofing	2.1	3.9	1.1	0.8
Mechanical				
Piping	3.4	11.6	23.9	16.1
Plumbing	2.2	3.7	1.5	1.4
Vessels	2.0	1.4	7.3	3.9
Heating, ventilation, air conditioning	6.5	8.4	2.3	2.9
Mechanical equipment	5.4	6.0	9.9	18.5
Other				
Special equipment installation	1.4	5.7	3.0	5.3
Electrical	8.5	11.3	15.0	14.1
Instrumentation	1.6	2.1	6.4	2.9
Insulation	0.8	0.9	3.8	1.6
Coatings, painting	2.0	1.0	2.1	1.6
Fireproofing	2.0	2.5	1.4	0.6

[a]Average project cost = $25 million; average peak work force = 300.
[b]Average project cost = $120 million; average peak work force = 600.
[c]Average project cost = $190 million; average peak work force = 900.
[d]Average project cost = $470 million; average peak work force = 1,600.

SOURCE: Business Roundtable (1982c).

Nature of Construction Projects

There is also considerable variety in the nature of construction projects. Table 2 summarizes the results of a survey conducted by the Business Roundtable (1982c) to develop profiles of four types of construction projects in terms of their costs and the work forces used. The four types were buildings, light and heavy industrial projects, and power plants. Many differences were found. For example, whereas civil construction (earthworks, foundation, structure, enclosure skin, interior finishing, and roofing) constitutes two-thirds of the cost of constructing a building, it is less than one-third of the cost of constructing a heavy industrial or power plant project. For those projects, the majority of cost is for mechanical and electrical work. Similarly, whereas almost two-thirds of the craftsmen on building projects perform civil and architectural work, the majority of workers on heavy industrial and power plant projects perform mechanical and electrical work.

Other Features

Other features distinguish the construction industry from most other industries. Among the most important are the seasonal and weather-sensitive nature of the work (see Employment Standards Administration, 1979), the wide swings in the demand for construction due to the industry's high sensitivity to fluctuation in interest rates; the location of every project at a different site, the fact that most projects involve the construction of one-of-a-kind facility, and finally, the degree to which voluntary standards (published by professional societies and trade associations) and mandatory regulations and building codes (promulgated by countless federal, state, and local government agencies) control construction.

The participants in the construction process, both individually and collectively, have accepted and adapted to these features. To a greater extent than in any other industry, construction workers move from job to job and from company to company with alacrity; firms expand, contract, and relocate with amazing speed; and diverse groups are able to organize quickly into an effective team to carry out a particular project.

THE FEDERAL ROLE IN CONSTRUCTION

For many years, the federal government has funded a substantial portion of U.S. construction work. Patrick MacAuley (1985) in Construction Review discussed the size and composition of the construction portion of the federal budget for the years 1980 to 1986. Among the points highlighted in the paper were the following:

TABLE 3 Major Construction-Related Direct Federal Programs for Fiscal Years 1980-1986 (millions of dollars)[a]

Direct Federal Programs[b]	1980 (actual)	1981 (actual)	1982 (actual)	1983 (actual)	1984 (actual)	1985 (estimated)	1986 (budget)
Military construction (10 accounts)	2,735	2,295	2,962	3,322	3,565	4,029	5,072
Housing, defence family housing (4 accounts), total	75	186	194	304	406	436	602
Highways and roads							
BIA road construction	76	70	47	45	23	11	3
USFS forest roads and trails	101						
USFS construction and land acquisition	267	486	420	402	292	261	223
USFS timber purchaser roads	54	53	48	45	38	34	23
Total	498	609	515	492	353	306	249
Hospitals and other health facilities							
H&HS Indian health facilities	87	89	65	66	69	58	70
NIH building and facilities	56	33	25	16	18	19	12
VA construction, major projects	190	308	345	338	353	425	581
VA construction, minor projects	105	96	83	91	123	140	157
Total	436	526	518	511	563	642	820
Conservation and development							
COE civil construction, general	1,659	1,536	1,453	1,258	1,103	1,100	980
COE flood control, Mississippi River	161	162	247	284	395	350	276
COE rivers and harbors contributed funds	34	84	65	45	50	56	96
Bureau of Reclamation, construction	437	591	569	600	656	703	700
Fish and Wildlife Service, construction	86	67	33	19	16	29	23
National Park Service, construction	137	134	87	106	104	96	93
Tennessee Valley Authority fund	1,758	2,103	1,178	1,244	518	1,310	1,286
Bonneville Power Administration, construction	104	148	192	160	206	234	201
Western Area Power Administration, construction	20	37	74	94	105	93	80
Total	4,396	4,862	3,898	3,810	3,153	3,971	3,735
Federal industrial structures							
Atomic Energy Defense, structures	397	470	852	920	908	1,242	1,322
Fossil Energy R&D, structures	137	161	52	10	13	14	4
General science and Research, structures	81	75	68	66	100	137	62
Uranium enrichment, structures	272	388	670	647	606	387	—
Energy supply R&D, structures	403	249	161	116	130	134	138
Strategic petroleum reserve, structures	254	200	158	178	192	241	161
Total	1,544	1,543	1,961	1,937	1,949	2,155	1,687
Other construction-related programs							
FAA airport facilities and equipment	230	252	292	248	268	500	845
Coast Guard acquisition, structures	32	29	30	55	54	62	61
BIA general construction	30	77	108	88	101	128	97
FPS Prison building and facilities	16	23	15	18	52	68	100
Washington airport construction	6	26	13	14	18	23	20
Architect of Capitol, construction	30	49	32	15	13	39	46
NASA construction of facilities	140	147	109	108	109	167	162
Social Security Administration, construction	32	16	33	48	38	44	37
GSA federal buildings, construction	11	34	43	179	122	202	49
GSA federal buildings, repair	87	139	148	168	265	279	357
BIA energy conservation	0	c	63	224	90	137	62
Total	614	792	886	1,165	1,130	1,649	1,836
Total, 36 major direct federal programs	10,300	10,813	10,934	11,541	11,119	13,188	14,001

[a]Does not include U.S. Postal Service construction, which totaled $232 million in 1982, $394 million in 1983, $585 million in 1984, and will total approximately $783 million in 1985.
[b]BIA, Bureau of Indian Affairs; USFS, U.S. Forest Service; H&HS, Health and Human Services; NIH, National Institutes of Health; VA, Veterans Administration; COE, Corps of Engineers; FAA, Federal Aviation Administration; FPS, Federal Prison System; NASA, National Aeronautics and Space Administration; GSA, General Services Administration.
[c]Less than $500,000.

SOURCE: Construction Review (March-April, 1985).

- Construction-related federal expenditures for fiscal year (FY) 1984 (which ended September 30, 1984) totaled almost $43.8 billion, of which approximately $11 1 billion were used for direct federal purchases (i.e., the 36 programs listed in Table 3), $21 billion were spent on 26 grant-in-aid programs (e.g., for highways, community development, and airports), and $11.6 billion were distributed under 30 construction-loan programs (e.g., for rural electrification, small businesses, and housing). Construction-related federal expenditures for FY 1985 are expected to total about $50.5 billion.
- During FY 1984, federal expenditures accounted for at least 15 percent of the value of all new construction put in place, and 65 percent of total public works construction. In addition to funding all federally-owned construction, the federal government also funded over 56 percent of state and local government-owned construction and at least 5 percent of all privately-owned construction (see Table 4).
- Federal spending for construction has grown most rapidly in the following categories: military facilities, highways, and rural electrification. Spending for federal hospitals, conservation and development, sewage treatment facilities, federal industrial facilities, and housing has remained level or has increased only modestly (see Table 5).
- Construction-related expenditures have accounted for a declining share of total federal expenditures in recent years. In FY 1980 they accounted for 7.9 percent of total federal spending plus lending, but by FY 1984 they accounted for only 4.9 percent.
- In addition to spending $43.8 billion on programs directly related to construction in FY 1984, the federal government also spent $38.8 billion on programs that are indirectly or only partially related to construction (e.g., the National Flood Insurance Fund, general revenue sharing grants, farm ownership loans, subsidized housing programs, General Services Administration real property operations, the hazardous waste superfund, and defense family housing maintenance). In FY 1984 the federal government also guaranteed $43.5 billion in construction-related loans for such things as housing, rural electrification, and energy resources development.

SUMMARY

The construction industry is a huge and vitally important element of the national economy. It accounts for more than 8 percent of the GNP and has a major impact on most other elements of the economy. The federal government must be concerned with the health and productivity of the construction industry both because of the importance of the industry to the economy and because directly or indirectly the federal government funds a significant percentage of all U.S. construction work. However, the construction industry is extremely complex and decentralized; consequently, its basic structure and method of operation are not easily directed or influenced by federal actions.

TABLE 4 Federal Construction-Related Expenditures by Ownership Category for Fiscal Years 1980-1986 (millions of current dollars)

Ownership Category	1980 (actual)	1981 (actual)	1982 (actual)	1983 (actual)	1984 (actual)	1985 (estimated)	1986 (budget)
Government-owned							
Federal	10,300	10,813	10,871	11,317	11,029	13,051	13,939
State and local	26,081	27,753	15,285	24,758	24,142	27,649	26,496
Total	36,381	38,566	36,156	36,075	35,171	40,700	40,435
Privately-owned							
Residential	7,539	8,321	8,115	8,437	6,044	6,264	3,666
Nonresidential	5,090	5,556	3,537	2,940	2,549	3,545	2,205
Total	12,629	13,877	11,652	11,377	8,593	9,809	5,871
Total construction expenditures	49,010	52,443	47,808	47,452	43,764	50,509	46,306

SOURCE: Construction Review (1985).

TABLE 5 Federal Construction-Related Expenditures by Types of Construction for Fiscal Years 1980-1986 (millions of current dollars)

Type of Construction	1980 (actual)	1981 (actual)	1982 (actual)	1983 (actual)	1984 (actual)	1985 (estimated)	1986 (actual)
Military construction	2,735	2,295	2,962	3,332	3,565	4,029	5,072
Highways and roads	9,011	9,197	8,180	9,469	10,584	13,186	13,943
Hospitals and other health facilities	552	630	601	564	577	674	846
Conservation and development	4,708	5,261	4,287	4,147	3,538	4,438	3,970
Sewage treatment facilities[a]	4,343	3,881	3,756	2,983	2,623	2,740	2,650
Federal industrial	1,544	1,543	1,961	1,937	1,949	2,155	1,687
Housing	7,733	9,329	9,041	9,215	6,603	6,700	4,268
Other construction-related	18,384	20,307	17,020	15,815	14,325	16,587	13,870
Total	49,010	52,443	47,808	47,452	43,764	50,509	46,306

[a]FmHa water and sewer loans and grants are classified as "other construction-related."

SOURCE: Construction Review (1985).

4

CONSTRUCTION PRODUCTIVITY IN THE UNITED STATES

PRODUCTIVITY MEASURES

Productivity measures are used to make comparisons of technical efficiency across different production units for a given time period or across different time periods for given production units. Any production process can be viewed as transforming certain inputs (land, labor, capital, and materials) into a good or service (such as a building or a haircut). Productivity is defined as the ratio of output to inputs. Increasing productivity is an important economic objective because it allows more goods and services to be produced from the same set of inputs.

Single-Factor and Multifactor Measures

There are two basic approaches to measuring productivity: single-factor and multifactor measures. Single-factor measures use only one input in the denominator. The most commonly used measure of productivity is labor productivity, the ratio of output to either employment or labor hours. In construction, square footage and dollar value put in place per hour are commonly used indicators of labor productivity. In certain situations, other single-factor measures might also be useful, such as capital productivity (the ratio of output to capital input) or land productivity (the ratio of output to land area).

When using any of these single-factor measures, care must be taken to avoid assigning causation of productivity change to whatever input happens to be in the denominator. Increases in labor productivity do not necessarily indicate that workers are becoming more skilled or putting forth greater effort. Higher labor productivity can also result from increases in the quantities of other inputs, especially capital, or changes in technology or organization. In fact, it is possible for labor productivity to increase while capital or land productivity decreases. In such cases, it is very difficult to determine what has actually happened to technical efficiency.

Because interpreting single-factor productivity measures is difficult, the multifactor approach was developed. Multifactor productivity measures use a weighted average of all inputs in the denominator. The weights usually correspond to each input's share of total

expenditures. Multifactor measures reflect the joint impact of all inputs on productivity more accurately than single-factor measures because the quantities of all inputs are in effect held constant, whereas only one input is held constant in the single-factor approach. Multifactor measures do not seem to be widely used in construction.

One important conceptual limitation of productivity measures is that they ignore the cost of inputs. Even if a new production technique promises greater productivity, firms will not choose to adopt that technique unless it lowers their costs. One way to take input costs into account is to use a unit cost measure, the ratio of input costs to output. A unit cost measure that is used frequently in construction is cost per square foot.

LIMITATIONS OF AVAILABLE DATA ON CONSTRUCTION PRODUCTIVITY

The BLS Productivity Index

The federal government currently does not publish any data on construction productivity. The Bureau of Labor Statistics (BLS) does compute a productivity index for the entire industry, but it is considered to be so deficient that it is not published. Nevertheless, it is widely disseminated and discussed. In the past, BLS also conducted studies on the quantity of labor, equipment, and materials required to build certain types of projects, but this program was discontinued in 1981 to save money.

The unpublished index (Table 6) is computed by dividing value added (total revenue minus subcontracting and expenditures for materials) for all establishments classified as being in the construction industry under the Standard Industrial Code (SIC) system by labor hours for those establishments. In order to make comparisons over time, value added must be adjusted for price changes. Since 1967, this index has indicated that productivity in construction has fallen.

There are three major limitations to the BLS productivity index. The most important of these is the deflator used to adjust for price changes. True price deflators are available for only two types of construction: single family houses and highways. For all other types, which represent two-thirds of the industry, indices of labor and materials costs are used in place of price indices. This causes the deflator to systematically overestimate the rate at which prices are increasing and, thus, underestimate the growth in output and productivity. This happens because the rate of growth in wages is directly related to productivity growth as well as inflation.

A second serious limitation is that this index totally ignores construction work by establishments that are not classified as being in the construction industry. For instance, some power companies use their own crews to build new plants. Because they are classified as public utilities, their construction activity is excluded from the index.

TABLE 6 Annual Index Values for Output per Employee Hour in the U.S. Construction Industry, 1947-1984 (1977 = 100)

Year	Index	Year	Index
1947	71.4	1966	115.3
1948	77.1	1967	116.2
1949	77.5	1968	121.8
1950	81.8	1969	110.9
1951	83.0	1970	108.3
1952	84.9	1971	113.0
1953	89.1	1972	112.0
1954	93.2	1973	106.6
1955	93.6	1974	94.9
1956	93.6	1975	98.0
1957	96.5	1976	102.9
1958	103.9	1977	100.0
1959	105.9	1978	95.7
1960	109.9	1979	89.8
1961	112.8	1980	83.0
1962	114.6	1981	82.4
1963	114.9	1982	86.2
1964	117.1	1983	85.5
1965	118.3	1984	84.2

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics.

The Business Roundtable's Construction Industry Cost Effectiveness (CICE) project recently reported another serious defect in the BLS index. The Business Roundtable (1982a) found that many projects, some costing $5 million or more, are not included in the tabulation of total output. In some cases, companies do not receive requests for data and in others, companies refuse to respond to requests because of the costs involved. Alan Blum (1980) of the Census Bureau presented corroborating evidence of this undercount. Blum found that the Census of Construction in 1977 reported 75 percent more industrial construction and 29 percent more hospital and institutional construction than the Value of New Construction Put in Place series used to estimate total output. The consequences of this undercount of output are not yet clear. If the labor hours used in the omitted projects are also not being counted, then the problems caused by the undercount are identical to those caused by the exclusion of construction work by establishments in other industries. If the labor hours in these projects are being counted, then this exclusion is resulting in an even greater systematic underestimation of output and productivity.

Even if the BLS index were not subject to these limitations, it would be useful mainly for the purposes of economic analysis, not for effective decision making by owners and managers of construction projects. It makes little sense to think that a single aggregate measure could apply to all types of construction; separate measures are needed for each of the major branches of the industry. Because the SIC system classifies establishments in construction as either general (e.g., building, highway) or special trade (e.g., plumbing, electrical) contractors, it is impossible for the federal government to use currently available data to construct measures for a representative spectrum of construction projects.

A few groups of construction company owners have begun to share productivity data collected from their own projects. Although this kind of information is no doubt better than no data at all, it is also likely to be of limited usefulness because it is not derived from random samples.

IS CONSTRUCTION PRODUCTIVITY DOWN?

Most assertions that construction productivity has dropped in recent years have been based on the BLS productivity index (see Table 6), which, as indicated above, has shortcomings that diminish its value as an indicator of national productivity trends. This does not mean, however, that a construction productivity problem does not exist. Rather, it means that the BLS statistics used to demonstrate the existence of a productivity problem are flawed and must be used with extreme caution.

Several investigators have analyzed the BLS statistics and other data to determine the true magnitude and causes of productivity changes that have occurred. Allen (1985) concluded that the actual drop in labor productivity between 1968 and 1978 was 8.8 percent, not 21.4 percent as indicated by the BLS index. He found that the BLS index

overstated the productivity drop primarily because it understated the real output of the construction industry. He attributed the productivity decline that occurred between 1968 and 1978 to "the reduction in skilled labor intensity resulting from the shift in the mix of output from large-scale commercial, industrial, and institutional projects to single-family houses" and, to a lesser extent, to "decline in the average number of employees per establishment, capital-labor ratio, percent union, and the average age of workers."

Stokes (1981) examined several possible reasons for the decline in construction productivity reported by the BLS: a shift in the nature of the output of the construction industry; a reduction in capital equipment used per worker, a drop in the average age of construction workers, changes in work rules, and problems relating to the measurement of productivity. He found that only about 25 percent of the productivity decrease indicated by the BLS index could be explained by these factors. He concluded, therefore, that "the productivity declines in the construction industry during the past decade are real."

Bourdon (1980) concluded that there has not been a severe drop in construction productivity. According to Bourdon, the BLS index is wrong because the deflator used by the Department of Commerce to adjust the value of construction put in place to constant dollars causes output (the numerator in the productivity equation) to be understated, and the fixed labor percentages used by BLS causes the input (the numerator) to be overstated.

Lange and Mills (1979) suggested that the problem is not that the BLS index is wrong per se. Rather, the index fails to account for the fact that facilities now being constructed by the industry are more complex and thus require more labor.

Schriver and Bowlby (1985) examined the causes of changes in square foot costs of buildings between 1972 and 1982. They concluded that there were "substantial declines in total factor productivity in [building] construction during 1980-1982 after adjusting for changes in the composition of output." However, they found no decrease in productivity during the 1972-1979 period.

Ball (1981), an economist in the BLS, used data from the BLS surveys of labor and material requirements for various types of construction activity (which were discontinued in 1981 due to budget cuts) to estimate changes in onsite employee-hour requirements between 1958 and 1976 per deflated dollar of construction for various categories of construction. He found that the number of site hours required had dropped (indicating a productivity increase) for all categories of construction. The average annual change (percent) in labor requirements for those categories in which sufficient data were available were as follows: federally-aided highways, 1958 to 1976, -1.5 percent; federal office buildings, 1959 to 1975, -2.2 percent; public housing, 1960 to 1975, -3.9 percent. For other categories of construction the span of years for which data were available was too narrow to be meaningful.

As an alternative to the BLS productivity index, the committee decided to use data from cost estimating manuals to determine construction

productivity trends. Dunlop also suggested this method in 1972. Using manuals published by the Robert S. Means Company, the committee compared the productivity of members of construction crews performing 30 different randomly selected tasks in 1975 and 1985, based on Means' (1974, 1984) data. The results, which are presented in Appendix A, suggest that there was no definite trend in construction productivity between 1975 and 1985, either up or down. Over the 10 year period, output per crew member increased for 13 tasks, decreased for 11 tasks, and remained unchanged for 6 tasks.

Although it is generally agreed that the BLS construction productivity index per se is inaccurate, the index is nevertheless occasionally used to compare the performance of the construction industry with other industries and to track the performance of the industry over a long period of time. Table 7, prepared by Martin Baily (1981), illustrates such usage. The table indicates that productivity increased at a slower rate in the construction industry than in any other industry during the 30-year period from 1948 to 1979, and that problems with construction productivity apparently began in the late 1960s.

CONCLUSIONS

It is difficult to show conclusively that construction productivity has actually decreased in recent years or, if it has decreased, to show the magnitude of the decrease. However, most evidence suggests that even if construction productivity has not actually decreased, it probably has not increased very much either, which is almost as bad. Furthermore, it is almost certain that productivity growth in construction has been slower than in other industries in the United States.

Undoubtedly, there is a need for more comprehensive and accurate measurement of construction productivity, not just at the macro-economic level, but also for various segments of the industry, types of enterprises, and individual tasks. However, efforts to improve productivity need not be deferred until more accurate estimates are available. There is already sufficient evidence that a productivity problem exists to justify action.

TABLE 7 Annual Growth Rates of Labor Productivity for the Nonfarm Business Sector and for Major Industries, Not Cyclically Adjusted, Selected Periods, 1948-1979

Sector and Industry	Annual Growth Rate of Labor Productivity (percent)				
	1948-1957	1957-1968	1968-1973	1973-1979	1948-1979
Nonfarm business[a]					
Manufacturing	2.64	2.82	3.52	1.51	2.63
Nonmanufacturing	2.14	2.76	1.04	0.25	1.82
Industries[b]					
Manufacturing	2.57	2.84	2.72	1.41	2.47
Agriculture	5.58	4.76	5.12	2.81	4.68
Communications	4.62	5.71	4.57	6.06	5.28
Construction	2.50	2.98	-5.15	-2.49	0.47
Utilities	6.78	5.16	3.19	-0.66	4.18
Finance, insurance, and real estate	2.42	1.70	0.07	0.89	1.49
Mining	4.11	4.29	0.20	-5.19	1.75
Retail trade	2.36	2.63	1.70	0.78	2.04
Wholesale trade	2.65	3.71	3.15	-0.44	2.51
Transportation	2.94	3.36	2.51	0.12	2.47
Services	1.19	1.82	2.01	0.14	1.34

[a]Data reflect the 1980 revision of the national income accounts.
[b]The 1980 revision is not yet available by industry, so these data are not directly comparable to other data in this paper.

SOURCE: Bureau of Labor Statistics.

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CONSTRUCTION-RELATED RESEARCH AND DEVELOPMENT IN THE UNITED STATES

Numerous studies have examined the relationship between productivity and R&D (e.g., see the volume edited by Griliches, 1984). Most researchers have expressed the relationship in terms of a rate of return on money invested in R&D. Although various researchers have calculated widely different rates of return, almost everyone has found that the rate of return is positive (i.e., money invested in R&D produces savings from increases in productivity that exceed the investment). For example, Clark and Griliches (1984) reported an overall rate of return on R&D of 20 percent while Griliches and Lichtenberg (1984) reported a 9 percent rate of return on R&D performed between 1959 and 1963, a 20 percent return on R&D performed between 1964 and 1968, and a 33 percent return on R&D performed between 1969 and 1973.

The fact that R&D can contribute to higher productivity has been recognized for many years. Thus, in the past when productivity problems of the construction industry have been analyzed and discussed, one frequently identified cause has been insufficient R&D (e.g., see Ashley and Tucker, 1984; and Business Roundtable, 1982b, c). However, because investments in R&D can contribute to productivity growth does not necessarily mean that the converse is true: that stagnant productivity is due to inadequate investment in R&D. In fact, various reasons besides insufficient R&D have been given for the lack of productivity growth in construction--for example, lack of investment in capital equipment, the fragmentation of the construction industry, out-of-date management practices, undertrained workers (especially foremen), slow adoption of new technology, jurisdictional disputes among unions, inefficient labor practices, and government regulations. Although such factors may have contributed to the productivity problems of the construction industry, the committee has concentrated on R&D both because that was its charge and out of conviction that inadequate R&D undoubtedly has been a major factor, though possibly not the only factor. Furthermore, it is possible that many of the contributing factors mentioned above would not have been present if more R&D had been performed, particularly R&D relating to the management of construction.

As part of its analysis of the current state of the U.S. construction industry, the committee decided to examine the nature and amount of

construction-related R&D actually being conducted in the United States and to try to assess whether the amount is inadequate, as has been asserted. Because, as noted previously, the construction industry is composedof many elements or subgroups, each with special concerns and motivations, the committee examine the R&D activities of the various subgroups separately.

R&D BY CONSTRUCTION CONTRACTORS

The committee found few statistics on R&D conducted by construction contractors--that is, general and specialty contractors involved in on-site construction. The National Science Foundation (NSF) prepares an annual report on R&D performed by industry (see NSF, 1983); however, the NSF combines R&D performed by construction contractors with R&D performed by other "non-manufacturing industries"--for example, agriculture, forestry, fisheries, mining and extraction, transportation, communications and other public utilities, wholesale and retail trade, finance, insurance, real estate, and selected service industries. Therefore, it is impossible to determine from the NSF data how much construction contractors spend on R&D.

Using data from the Federal Trade Commission's line of business survey of 1974, Scherer (1984) estimated that construction contractors spent $28 million on R&D in 1974, which represents about $54 million in 1984 dollars. (See "R&D by Manufacturers" below for further discussion of Scherer's work.) Although this is not an insignificant amount of money, it is minuscule for the size of the industry, and it does not invalidate the conclusion by many that construction contractors spend almost nothing on R&D (e.g., Business Roundtable, 1982b).

The committee is aware of only a few large contractors that have R&D offices, and many of these are concerned primarily with product evaluation. Some of the construction trade associations have R&D programs, but in general they do not receive much support from contractors. For example, the R&D arm of one of the largest associations, which has many thousands of members, spends only about $150,000/year on R&D requested and funded by association members. (This same association receives approximately $3 million/year for R&D through contracts with various government agencies and private manufacturing corporations.) Most trade associations spend even less or nothing on R&D.

One interesting recent development is the proposal of the International Union of Bricklayers and Allied Craftsmen to greatly increase the R&D program of the International Masonry Institute (which is jointly sponsored by the union and the Mason Contractors Association of America) through collectively bargained payments by masonry contractors. Under the proposal, the annual R&D budget of the Institute would increase from the current level of about $150,000 per year to $20 million per year in ten years. It is presumed that the payments to the Institute would be based on the number of hours worked by union members. (Project 2000 Committee, 1985)

The committee believes that contractors generally have not supported R&D for one or more of the following reasons:

- A belief that onsite construction is a service industry and that responsibility for conducting construction R&D rests primarily with the manufacturers of the equipment, products, and materials used by the industry.
- A belief that it seldom pays a construction contractor to conduct R&D because the results of construction-related R&D generally cannot be patented, and competitors will quickly learn of and use anything worthwhile that is developed.
- A belief that overhead expenses like R&D must be kept to a minimum in order for a construction firm to survive the periods of low activity that are common and inevitable in construction.
- A belief that only very large organizations can afford to conduct R&D.

Although construction contractors do not support R&D, there has been considerable innovation in onsite construction over the years. Much of the innovation, of course, has resulted from the introduction of new equipment and products by manufacturers. However, contractors themselves also have developed new and better work methods. In most cases, such developments have resulted from on-the-job experimentation rather than formal R&D programs; consequently, such developments do not show up in statistics, and their value and cost cannot be measured.

R&D BY DESIGN PROFESSIONALS

The committee found no published statistics on R&D performed by design professionals (i.e., architects, engineers, and other professionals in private practice who specialize in the design of buildings and similar facilities). The most likely reason for the lack of statistics is that professionals probably spend very little of their own funds on R&D. Whatever the amount, the committee has no doubt that it represents a tiny percentage of annual expenditures on construction-related design services.*

The committee believes that many design professionals do some R&D as a normal part of the design process, and that some design firms occasionally undertake investigations for clients that could be considered R&D. However, it would be difficult to determine how much R&D work of this kind is performed throughout the country because most professional firms do not keep separate records on such work.

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*The committee estimates that expenditures for construction-related design services average 5 percent of total construction expenditures. Thus for 1984, expenditures for design services probably totaled about $15 billion.

Many design professionals support the R&D programs of the professional societies to which they belong. However, such programs are very small. For example, contributions during the 1984-1985 fiscal year to the research program of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) totaled slightly less than $800,000, and a substantial percentage of that amount came from manufacturers (ASHRAE, 1985). ASHRAE membership totals almost 50,000; thus, the average individual member contributed less than $20. Other professional societies with R&D programs probably receive comparable support from their members.

R&D BY MANUFACTURERS OF CONSTRUCTION PRODUCTS AND EQUIPMENT

Statistics on R&D by manufacturers are published by many organizations (see Business Week, July 8, 1985; Inside R&D, June 5, 1985; NSF, 1983). Unfortunately, such statistics are of limited value in this study because they show R&D expenditures by categories of products (e.g., appliances, automotive, chemicals, electrical, metals, paper, and steel), which are used partly by the construction industry and partly by other industries. Thus, except for products that are specifically associated with construction, the published statistics do not show how much manufacturers invest in R&D on products used by the construction industry.

The Business Week statistics include one product category, building materials, that is clearly linked to construction; corporations in this category spent $184.1 million on R&D in 1984. A portion of another product category, farm and construction machinery, is also clearly linked to construction; corporations in this category spent $769 million on R&D in 1984. However, it is not known how much of the latter amount was used for construction equipment R&D and how much was for farm equipment R&D.

Scherer (1982, 1984) developed an analytical technique for determining how the benefits of R&D performed by one industry flowed to various other industries. He presents his results in a matrix that shows the pro rata benefits that accrue to various industries from the R&D performed by other industries with which they do business. The starting points for the matrix were the 1972 input-output tables for the U.S. economy and the Federal Trade Commission's 1974 line of business survey. It includes only company financed R&D expenditures.

Scherer's analysis indicates that although the construction industry itself does little R&D, it uses and benefits from R&D performed by other industries (mostly manufacturing). For example, in 1974 the construction industry benefited from approximately $432 million in R&D expenditures from 33 other industries, as indicated in Table 8. In 1984 dollars, these expenditures total more than $838 million. In most cases the construction industry benefited indirectly from R&D performed by other industries through better products and services. It is not known whether such indirectly-acquired R&D has the same impact on productivity as R&D performed by an industry itself.

TABLE 8 Benefits Derived by the Construction Industry from R&D Performed by Other Industries (millions of 1974 dollars)

Industry	Amount[a]
Food and tobacco products	0.3
Textile mill products	0.8
Lumber and wood products	0.3
Furniture	0.6
Paper mill products	1.4
Printing and publishing	0.4
Industrial inorganic chemicals	1.0
Industrial organic chemicals	0.6
Synthetic resins, fibers, rubber	1.1
Agricultural chemicals	0.1
Paints, toiletries, explosives and other chemical products	16.3
Petroleum extraction and refining	6.1
Rubber and plastic products	9.7
Stone, clay, and glass products	9.0
Ferrous metals	1.6
Nonferrous metals	0.4
Fabricated metal products	17.1
Engines and turbines	10.2
Farm machinery	2.4
Construction, mining and materials handling equipment	154.4
Metalworking machinery	6.6
Other machinery	20.5
Computers and office equipment	2.3
Industrial electrical equipment	1.8
Household appliances	0.2
Lamps, batteries, ignition, X-ray and other electrical equipment	5.7
Radio and communication equipment	16.1
Electronic components	1.7
Motor vehicles and equipment	125.1
Aircraft	0.5
Measuring and medical instruments, photo equipment and timepieces	13.9
Miscellaneous manufacturers	1.6
Construction and services, including R&D services	2.2
Total	432.0

[a]Share of R&D performed by the indicated industries that benefited construction industry.

SOURCE: Scherer (1984).

R&D BY CONSTRUCTION INDUSTRY CONSUMERS

Because almost everything man-made that remains stationary is either assembled, installed, or enclosed by the construction industry, almost every person and organization in the country is, at some time, a consumer of the industry. Of course, most individuals and organizations deal with the industry infrequently; consequently, they have no long-term interest in construction technology. There are many organizations,however, that have large, continuing construction programs, and some of these undertake construction-related R&D.

Private Corporations

The committee found no published statistics on the amount of construction-related R&D by private corporations that are construction consumers. Although the committee knows that such organizations sometimes undertake R&D projects (often through contracts with professional firms and academic institutions), the committee does not know the amount invested in such work each year. The committee is certain, however, that the amount is small in comparison to the construction expenditures of large corporations. The committee also believes that such projects usually deal with problems concerning specific facilities rather than broad issues of concern to the construction industry. Thus, such R&D probably has little impact on construction productivity.

There is evidence, however, of growing interest on the part of large, private construction consumers in R&D on broad issues. For example, large consumers make up most of the membership of the Business Roundtable, which conducted the widely publicized Construction Industry Cost Effectiveness (CICE) study (see Business Roundtable, 1983). In addition, construction consumers comprise approximately one-half of the membership of the Construction Industry Institute (CII), which is undertaking studies of a number of basic issues. Currently, the CII, which is located at the University of Texas, has about 60 members, each of whom contributes $25,000/year.

Government Organizations

The committee also could find no published statistics on construction-related R&D by state and local governmental organizations that procure construction, except for highway research, and most of the money spent for highway research by state and local governments actually comes

from federal agencies.* Nevertheless, the committee is confident that state and local governments spend very little on other construction-related R&D. The committee is aware that several of the associations that serve state and local government officials (e.g., American Association of State Highway and Transportation Officials; and the American Public Works Association) conduct construction-related R&D projects. However, the nature and magnitude of these efforts is not known.

The committee found detailed R&D statistics for only one category of construction consumer--federal government agencies. These statistics are published regularly by the NSF; however, because NSF categorizes R&D by technical discipline, not by the purpose of the R&D, the statistics do not show federal expenditures on construction-related R&D per se.

The NSF R&D category that is most closely associated with construction is civil engineering, and although it is neither exclusively associated with construction, nor the only discipline involved in construction, it is close enough to provide some insight into federal expenditures on construction R&D.

The committee obtained additional information on the construction-related R&D efforts of several agencies through direct briefings (see Appendix B). Table 9 shows the estimated R&D expenditures of various agencies based in part on NSF data and in part on the briefings. On the basis of the briefings, the committee believes that most of the R&D work of the agencies listed deals with the design of agency facilities and not construction technology. Statistics indicate that the construction arms of some agencies (e.g., the Departments of the Army, the Air Force, and Energy) spend substantial amounts on R&D whereas other agencies spend little or nothing.

R&D BY FEDERAL AGENCIES THAT ARE NOT CONSTRUCTION CONSUMERS

As noted in Chapter 3, several of the federal agencies that are not consumers of the construction industry have an interest in various aspects of construction and consequently conduct or fund some construction-related research. The NSF, for example, provides grants to academic institutions for a wide variety of R&D projects. Similarly, the National Bureau of Standards conducts R&D at its own laboratory on a broad spectrum of construction-related issues. Statistics on the R&D expenditures of these nonconsumer agencies are included in the NSF statistics on federal R&D (NSF, 1984a).

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*Of the approximately $72 million spent on highway research in the United States in 1982, approximately $1 million was spent by cities and counties and $39 million was spent by state highway departments. However, all but $5 million of the money spent by the states actually came from the U.S. Department of Transportation. Federal agencies also directly funded almost $29 million in highway research directly. (Transportation Research Board, 1984).

TABLE 9 Estimated Annual Construction-Related R&D Expenditures of Federal Agencies Responsible for Procuring Construction (millions of dollars)

Department/Agency	R&D Expenditures
Department of Agriculture,	
Forest Service	1.9[a]
Department of Defense:	
Army Corps of Engineers	42.7[b]
Naval Facilities Engineering Command	4.0[b]
Air Force Civil Engineering	33.0[b]
Department of Energy	32.2[a]
Department of the Interior,	
Bureau of Reclamation	3.3[a]
General Services Administration	.2[a]
National Aeronautics and Space Administration	1.0[a]
Veterans Administration	1.0[b]
Total	119.3

[a]Source: National Science Foundation (1984a). Includes applied civil engineering research for 1983 and basic civil engineering research for 1984.
[b]Source: Briefings given to the committee (see Appendix B). Includes research, development, testing, and evaluation for FY 1985.

As discussed above, the NSF statistics on civil engineering R&D by federal agencies do not relate to construction per se; they do, however provide a general indication of the level of federal funding for construction-related R&D. Table 10 shows annual expenditures totaling greater than $100 million for civil engineering R&D by agencies that do not procure construction. The committee has no basis for estimating what percentages of that amount might be devoted to R&D on construction technology, on other construction-related matters like design, or on civil engineering topics unrelated to construction.

R&D BY ACADEMIC INSTITUTIONS

In addition to statistics on R&D expenditures by industry and by federal agencies, the NSF also publishes statistics on R&D expenditures by academic institutions. Recently, NSF (1984b), reported that academic institutions spent almost $107 million on civil engineering research (both basic and applied) in 1983, the last year for which statistics were available. This total is misleading, however, because a substantial portion of the R&D funds spent by academic institutions are provided by federal agencies and private corporations. In fact, the committee believes that academic institutions spend very little of their own funds on construction-related R&D.

OTHER SPONSORS OF CONSTRUCTION-RELATED R&D

A number of organizations that do not fit in any of the previously discussed categories also sponsor some construction-related R&D. For example, a few private charitable foundations (e.g., the Ford Foundation and the Pierce Charitable Trust) have funded some construction R&D, as have some labor unions. A notable example is International Union of Bricklayers and Allied Craftsmen, which (as discussed above in connection with R&D by contractors) supports R&D through the International Masonry Institute and the Masonry Research Foundation. The committee has no statistics on the total dollar amount of R&D funded by such organizations; however, it is probably not a large amount.

THE ADEQUACY OF CONSTRUCTION-RELATED R&D

The key question regarding construction-related R&D is whether the current level of R&D is inadequate, as has been asserted. Since R&D for an entire industry like the construction industry is inherently an amorphous, open-ended activity, there are no clearly defined goals and milestones that can be used to judge the adequacy of the industrys R&D investments. The only way to make a judgment is through the use of various comparisons and indirect indicators. Since, as noted at the beginning of the chapter, economists have established a definite link

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TABLE 10 Estimated Annual Expenditures on Civil Engineering R&D by Federal Agencies That Are Not Primarily Responsible for Procuring Construction (millions of dollars)[a]

Department/Agency	R&D Expenditures
Department of Agriculture,	
Agricultural Research Service	2.2
Department of Commerce:	
National Bureau of Standards	6.7
National Oceanic and Atmospheric Administration	2.1
Department of Housing and Urban Development	0.1
Department of Interior:	
Geological Survey	4.6
Minerals Management Service	0.9
Office of Surface Mining Reclamation and Enforcement	0.2
Department of Transportation:	
Federal Aviation Administration	8.1
Federal Highway Administration	2.5[b]
Federal Railroad Administration	1.0
Research and Special Programs Administration	.3
Urban Mass Transportation Administration	17.8
Agency for International Development	3.0
Environmental Protection Agency	22.0
Federal Emergency Management Agency	0.2
National Science Foundation	29.1
Total	100.8

[a]Includes applied research for 1983 and basic research for 1984.
[b]The Federal Highway Administration actually transferred more than $30 million to the states for highway planning and research. NSF reports only funds used for basic and applied research.

SOURCE: NSF (1984a).

between R&D investments and productivity, one indicator of the adequacy of the R&D investments of an industry is the productivity of that industry. Thus it can be argued that the mere presence of a productivity problem in construction is prima facie evidence of inadequate investments in construction R&D, and indeed that argument has been used frequently, either implicitly or explicitly, in previously cited reports on the subject to justify the need for more construction-related R&D. Without disputing the validity of that argument, the Committee decided to try to see if the comparisons discussed below would shed further light on the question of the adequay of the current level of investments in construction R&D in the United States.

Working Estimate of Total Annual R&D Expenditures

In order to make comparisons, the committee needed an estimate of the total annual expenditures for construction R&D in the United States. Because detailed statistics are unavailable, the committee developed a working estimate that it deemed sufficiently accurate for its purposes.

To develop the working estimate, the committee began with the R&D funding categories for which it had at least rough estimates of current annual expenditures. These were: construction contractors (both general and specialty), $54 million; manufacturers of construction products and equipment, $838 million; and federal agencies (both consumers and nonconsumers), $220 million. The committee then assumed that R&D expenditures by all other members of the construction community would not exceed 10 percent of the sum of these expenditures, that is, 10 percent of $1.112 billion or $111 million. The committee decided that the sum of these ($1.223 billion) could be used for comparative purposes as an approximate working estimate of total annual construction-related R&D in the United States.

Construction R&D vs R&D in Other Industries

Using $312 billion (the value of construction put in place in 1984) as the total annual sales of the construction industry, the industry's R&D investments, expressed as a percentage of sales, equal 0.39 percent. This compares to the following percentages reported in Business Week (1985) for other mature industries: appliances, 1.4 percent; automotive, 1.7 percent; containers, 0.9 percent; food and beverage, 0.9 percent; fuel, 0.7 percent; oil service and supply, 2.9 percent; paper, 1.0 percent; steel, 0.5 percent; textiles and apparel, 0.8 percent; tobacco, 0.4 percent.

Assuming that the construction industry, including manufacturers that supply construction products and equipment, employs about 8.6 million workers, the dollar value of R&D expenditures per employee equals about $142. The comparable figures from Business Week for the

previously listed industries are as follows: appliances, $1,231; automotive, $1,498; containers, $877; food and beverages, $1,015; fuel, $3,110; oil service and supply, $2,348; paper, $1,261; steel, $740; textiles and apparel, $571; tobacco, $267.

Both of these comparisons show that the construction industry invests less for R&D than other mature industries.

Federal R&D in Construction vs Federal R&D in Other Fields

Although the current level of federal investments in construction R&D--approximately $220 million/year--is substantial, it is not large in comparison to the amount spent by the federal government on construction ($44 billion/year), nor is it large compared to federal spending for R&D in other fields. For example Schwartz (1985) reports that in 1984 the federal government spent $29.29 billion on defense R&D; $4.78 billion on health-related R&D; $2.30 billion on space R&D; $2.58 billion on energy R&D; $1.68 billion on general science R&D; $1.04 billion on transportation R&D; $0.96 billion on R&D regarding natural resources and the environment; $0.76 billion on agricultural R&D; and $0.20 billion on R&D regarding education, training, employment, and social services.

Construction R&D in Foreign Countries

The committee also hoped to compare the amount of construction R&D conducted in the United States with the amount conducted in other industrialized countries. Unfortunately, the committee could find few statistics on construction R&D in various foreign countries. The United Nations has published some data on the number of individuals in construction research in various countries (UNESCO, 1980); however, the number of countries reported is limited (the United States, for example, is not included) and the data appear suspect (e.g., researchers are numbered only in the hundreds in most industrialized countries).

Although statistics were unavailable on construction R&D in foreign countries, the committee learned that similar concerns about inadequate construction R&D have been expressed in other countries. A report by Revay and Associates (1983), for example, concluded that "the amount of construction R&D performed in Canada...is exceptionally small, amounting to only 0.1 percent to 0.2 percent of the value of the annual construction program." The report also suggested that the Canadian federal government needed to take action. Similarly, a report by the Swedish Council for Building Research (1983) expressed great concern about the low priority given to construction R&D in Sweden. It suggested that both government and industry should increase their construction R&D efforts to ensure that the Swedish construction industry remains internationally competitive. It should be noted that the Swedish government already invests more heavily in construction R&D (relative to the GNP of the country) than does the U.S. government. In 1980, for example,

construction expenditures in Sweden totaled about $15 billion (in U.S. dollars), and the Swedish Council for Building Research (a government organization) spent about $60 million (U.S.), or about 0.4 percent of construction expenditures.

There is evidence that contractors in at least one foreign country, Japan, are investing considerably more in construction-related R&D than their U.S. counterparts. For example, Suzuki (1984) reported that the Taisei Corporation (one of the largest construction firms in Japan) invests approximately $30 million/year (roughly 0.7 percent of sales) in R&D. It is doubtful that any large U.S. construction firm invests even a fraction of that amount in R&D.

Albus (1985) verified that Japanese construction firms invest heavily in R&D. He reported that Taisei Corporation had a Technical Research Institute with a staff of 130 researchers; Takemaka Corporation has a Technical Research Laboratory employing 256 people; Hazama Gumi, Limited, has a large research laboratory (size not specified) doing advanced research on tunneling and other subjects; Shimuzu Construction, Limited, supports a Research Institute employing 213 people; and Kumagai Gami Company, Limited, has an Institute of Construction Technology of undisclosed size doing research on various subjects.

The fact that several large Japanese construction firms invest large sums of money in R&D, whereas their U.S. counterparts spend almost nothing, does not by itself prove anything. It is possible, for example, that the Japanese firms are merely wasting money (as some U.S. construction company officials have suggested), or that the nature of the construction business in Japan is so different from the United States that comparisons are meaningless. On the other hand, the potential significance of the heavy investment in R&D by Japanese firms in comparison to their U.S. counterparts cannot be ignored.

CONSTRUCTION R&D CAPACITY IN THE UNITED STATES

One related issue that the committee explored was whether the United States has the human and physical resources (i.e., researchers and laboratory facilities) needed to effectively carry out a significantly expanded construction R&D effort. The answer, the committee concluded, was a qualified yes.

The committee members believe, based on personal knowledge of the situation, that the construction R&D laboratories of most manufacturers, government agencies, academic institutions, and other research organizations are not currently operating at capacity, and that they could expand their operations somewhat almost immediately. The ability of these institutions to expand their activities further would depend most on how quickly academic institutions could produce additional, well qualified researchers.

The evidence suggests that the supply of new researchers could be increased significantly within a few years. The Construction Education Committee of the Associated General Contractors (1985) reported that at

the end of 1984 over 150 universities and 4-year colleges in the United States offered construction programs. Approximately 16 of these are accredited by the American Council for Construction Education. Most of the remainder are accredited by the Accreditation Board for Engineering and Technology--21 as construction programs and the rest as options or areas of specialization in civil engineering, architecture, or some other discipline. The AGC Construction Education Committee also reported that 57 colleges and universities offered advanced degrees in some construction-related field. Since most researchers are produced through graduate programs, this is probably a better indicator of the current capacity of academic institutions to supply researchers than the total number of schools with construction programs. Although the number is low, past experience indicates that academic institutions can develop new graduate programs very quickly when there is a demand for them. Furthermore, formal education in construction is not needed for all construction-related R&D. Indeed, a considerable portion of such R&D can be and already is performed by engineers and scientists whose formal education has not included any courses in construction per se, and if the need arises, there are thousands of mechanical, electrical, industrial, and chemical engineers, and physicists, chemists, and mathematicians who could be quickly recruited and trained to do construction-related R&D.

CONCLUSIONS

It has been clearly demonstrated that, as a general rule, investments in R&D result in productivity gains that more than offset the investment. There is no reason to believe that the construction industry does not follow this rule. Therefore, it can be assumed that the productivity of the construction industry has benefited from R&D in the past and that it would benefit from increased R&D in the future.

The committee's analysis of construction-related R&D in the United States indicates that the total annual investment in R&D by all elements of the construction community probably totals about 0.39 percent of the annual value of construction put in place. Manufacturers of construction products and equipment probably account for almost 69 percent of all construction-related R&D in the United States, government agencies for about 18 percent, contractors for about 4 percent, and all other elements of the building community for about 9 percent.

The U.S. construction community, (including users, manufacturers, contractors, government agencies, and others), probably invests proportionally less in R&D than any other United States industry. It also probably invests less in R&D than the construction industries in some foreign countries, notably Japan. In addition the federal government invests less in construction R&D than in other R&D.

Based on the lack of increase in the U.S. construction productivity over the past 20 years and the low rate of investment in construction R&D, the committee concludes that construction R&D has been inadequate

in the United States and needs to be increased. Because of the complexity and diversity of the construction industry, it is impossible to determine precisely how much of an increase in R&D is needed. It is apparent, however, that the current level of investments in R&D is sufficiently low that the amount of R&D could easily be increased several fold before the point of diminishing returns is reached.

The committee also concludes that there is little reason to hope that the increase will come from the private sector. Although the existence of a construction-productivity problem has been recognized and discussed for many years, the amount spent on R&D by private members of the construction community (except manufacturers) has remained low. It seems unlikely that the factors that have caused this situation (e.g., the attitudes of those involved, the cyclical nature of construction activity, and the structure of the industry) would change now. While it is possible that some type of special tax incentive might be devised to encourage more private investment in construction-related R&D, this also seems unlikely. Tax incentives for R&D investments applicable to all segments of industry have existed for many years, and they have not resulted in any massive investment in construction R&D yet. Furthermore, it seems unlikely that additional incentives would be enacted especially for the construction industry. Therefore, if there is to be an increase in construction R&D, some direct action by the federal government will be required.

Finally, although relatively few academic institutions currently offer undergraduate and graduate degrees in construction per se (i.e., the management of construction projects and the technology of construction work), the number would probably increase rapidly if the demand for construction researchers increased. Furthermore, there are thousands of engineers and scientists who could be recruited and trained to do construction-related research even though they have not taken any construction courses. Thus, while an increase in spending for construction R&D might produce a temporary shortage of construction researchers, the shortage would not persist. Therefore, the fact that the number of construction researchers currently is limited would not limit for very long the size of the U.S. construction R&D effort.

6

LESSONS FROM PREVIOUS GOVERNMENT EFFORTS TO PROMOTE TECHNOLOGICAL DEVELOPMENT

Over the years, the federal government has initiated countless programs to promote industrial innovation or scientific or technological development of some type, and while many have been successful, many others have failed. As part of its investigation, the committee reviewed the results of previous or ongoing federal efforts to promote technological development in an effort to determine whether a new R&D program would be likely to succeed, and if so, what kind of program would have the best chance.

A review of the literature revealed that in the past federal R&D activities have frequently been evaluated by politicians, economists, accountants, scientists, engineers, and others. In general, the evaluations have been of three kinds: analyses of the broad economic impacts of federal R&D in general or of specific large-scale, multifaceted programs, like the defense R&D program; detailed analyses of the results achieved from specific programs (both large-scale and narrow in scope), usually in terms of the stated program objectives; and discussion of the politics of federal R&D programs. The committee's findings are summarized below.

BROAD ECONOMIC IMPACTS OF FEDERAL R&D PROGRAMS

To evaluate the impact or benefits of federal R&D programs in macroeconomic terms, most economists have used one or more of the following indicators: rate of return on R&D investments (measured by growth in output of goods and services), number of patents filed or number of patents commercialized or both, and the impact of federal R&D on private R&D spending. Because of the macro nature of the available data, most economists are primarily concerned with the impact of the R&D programs of the federal government as a whole or of specific large-scale R&D programs like the defense program. In general, economists have not evaluated small, narrow-scope R&D programs.

The most striking theme that runs through most papers on the broad impacts of federal R&D efforts is that the available data or analytical tools to evaluate the data or both are inadequate to the task. Hertzfeld (1985), for example, after reviewing the efforts of various

organizations and individuals to measure the economic impact of federal R&D activities relating to civilian space programs concluded that "measuring the magnitude of the long-term economic impacts is nearly impossible. About all that can accurately be said is that the impacts will occur and that they will be sizable." He further concluded that "no economic study should attempt to put a bottom line ratio or return on space R&D investments. There is no such number in existence--it only lives in the uncharted world of general equilibrium theory. All such numbers that have been used as representative of a total return to space R&D have actually measured partial returns." Similarly, Weaver (1985) expressed skepticism about the validity of various analyses of the benefits of agricultural R&D programs, even though all but one of the eleven analyses he reviewed showed sizable rates of return. Mowery, (1985), Reiss (1985), and Terleckyj (1985) have also noted the limitation of current economic models for evaluating the impact of federal R&D.

Although most economists freely admit the inadequacies of the available data and tools, they seem to have reached consensus on several conclusions regarding federal R&D. One is that federal R&D programs as a group produce significantly lower rates of return than private R&D investments. However, many economists (e.g., Lichtenberg, 1985, Reiss, 1985, and Terleckyj, 1985) also caution against assuming from these lower rates that federal R&D programs are not beneficial. They note that the benefits of federal R&D usually cannot be observed statistically by traditional techniques. Reiss (1985), for example, suggested that "we will never be able to measure some of the consequences of federal R&D. For example, the political benefits of a strong national defense or a sophisticated space program are difficult to reduce to numbers as is the desirability of income redistribution caused by technical change. There are also some benefits that are potentially quantifiable, but for which we presently lack adequate data. Our limited progress in quantifying health care improvements is a ready example...."

Similarly, Terleckyj (1985) observed that in spite of the difficulties associated with proving it, "there is no reason to think that government financed R&D programs aimed directly at raising productivity either of particular industries or of the economy in general do not succeed in this objective."

Another generally-accepted conclusion among economists about federal R&D is that it complements rather than substitutes for private R&D (Reiss, 1985). This means that federal R&D programs generally do not cause private firms to cut their R&D expenditures. The conclusion is based on the work of several economists, including Mansfield (1984), who surveyed 25 major industrial firms to determine how their energy R&D efforts were affected by federal R&D support for energy research. Mansfield found that in many cases federal R&D funding actually stimulated additional private R&D investments.

Finally, economists now generally believe that government R&D programs tend to increase the cost of private R&D. Lichtenberg (1985), for example, reported that "there is reasonably strong econometric

evidence that supports the hypothesis that increases in federal R&D result in significantly higher starting salaries for scientists, engineers, and technical personnel, at least in the short run," and that this increases private R&D costs. He also noted, however, that the effect is probably much less (perhaps even zero) in the long run. When federal R&D programs are first initiated the supply of researchers is relatively inelastic, causing salaries of researchers to rise. After colleges and universities have responded to this need, salaries stabilize. It is sometimes suggested that the tendency of federal R&D programs to increase private R&D costs is offset by the contributions of federal R&D to general knowledge, which would tend to reduce private R&D costs. However, Lichtenberg (1985) concluded that "evidence regarding the incidence of cost-reducing (from the perspective of private R&D sponsors) spillovers from federal R&D is extremely limited."

GENERAL CRITIQUES OF MISCELLANEOUS FEDERAL R&D PROGRAMS

In the past, various researchers, committees, and government officials have analyzed the results of individual programs or groups of programs the federal government has undertaken to promote industrial innovation or scientific or technological development of some kind. Some of these programs have lasted for many years; others were terminated shortly after they began. These analyses were designed to determine if the programs succeeded, either in terms of the original objectives or possibly in ways not originally anticipated. Such critiques often have been somewhat subjective, either because the original program objectives were unclear or because detailed results were unavailable and prohibitively expensive to obtain.

As part of its investigation, the committee reviewed several programs that had been carefully critiqued by individuals and organizations as described above; the results are summarized in Appendix C. The programs represent a cross section of those undertaken by the federal government, and include: Operation Breakthrough, the Civilian Industrial Technology Program, the Industrial Energy Conservation Program, the National Shipbuilding Research Program, the Experimental Technology Incentives Program, the Research Applied to National Needs Program, the U.S. Department of Agriculture's science and education programs, the federal highway research programs, and the Modular Integrated Utility Systems project.

On the basis of its reviews, the committee found that the government has been involved in a wide variety of efforts, some of which have been very successful and others, failures. A single explanation for the failures is not readily apparent. Some programs seem to have failed (or in some cases have never really gotten started) because of political opposition based on budgeting concerns, opposition by the academic research community or the targeted industry, or congressional concerns about the appropriateness of the proposed effort. Other

programs seem to have suffered from faulty planning, poor management, or technical difficulties. Similarly, there appears to be no single explanation for the success of some R&D programs.

Four previous government efforts to promote technological development are particularly relevant to this study: Operation Breakthrough, The Civilian Industrial Technology Program (CITP), the various federal highway research programs and the federal agricultural research programs (see Appendix C). Although Operation Breakthrough and CITP are generally regarded as unsuccessful, they are relevant here because they were directed specifically at the construction industry. In the case of Operation Breakthrough, the problems appear to have been due to a combination of technical difficulties and excessive haste; CITP's failure was probably related to political considerations.

The federal highway research programs and agricultural research programs are relevant because they involve industries similar to the construction industry. They are among the most successful long-term R&D efforts of the federal government and their success has probably been due to two factors: (1) they satisfy real technical needs; and (2) they have been adroitly planned and managed to ensure continuing political support.

THE POLITICS OF FEDERAL R&D PROGRAMS

Observers of government affairs have recognized for many years that political and other nontechnical considerations often determine the success or failure of federal R&D efforts. The views of several observers are summarized below.

Fundingsland (1984) reviewed General Accounting Office studies of "mission-targeted" R&D projects, including the Liquid Metal Fast Breeder Reactor program, R&D to support regulation at the Environmental Protection Agency, water-related research, the Small Business Innovation Research Program, the Urban Tracked Air Cushion Vehicle program, Federal Short Take-off and Landing Air Transport programs, The Experimental Schools program, and The Operation Breakthrough housing program. Based on his reviews, Fundingsland made the following recommendations regarding government sponsored R&D:

- Discontinue the somewhat arbitrary practice of distinguishing basic from applied research, but separate all generic research from mission-targeted R&D in the federal budget.
- Use different criteria and a longer-range perspective for resource allocation among fields of science in generic research than for mission R&D.
- Continue the policy that the government will not support research that is adequately funded by the private sector.
- Explicitly acknowledge that the stability and continuity of federal research funding is more important than the actual level of support.

- Establish a long-term investment strategy for federal support of generic research that assures a minimum threshold and moderate growth, and is insulated but not isolated from fluctuations in the economy and changing priorities of each administration.
- Provide multiyear funding for R&D, especially for generic research.
- Let mission-targeted R&D absorb most of the adjustments that reflect changing priorities constrained by a short-term economic outlook and budget limitations.

Teich (1985) critiqued the Civilian Industrial Technology Opportunities Program, Industrial Innovations Incentives, the NSF Interdisciplinary Research Relevant to Problems of Our Society program and the Research Applied to National Needs program, federal funding for alternative energy R&D and demonstrations, the Cooperative Automative Research Program, aeronautics research of National Advisory Committee on Aeronautics and National Aeronautics and Space Administration, agricultural research, applied research in the biomedical field, general research at the National Bureau of Standards, and some aspects of Department of Defense research.

Teich identified four points that need to be considered in developing federal R&D programs:

1. Modesty in defining and promoting the programs seems useful. Grandiose plans tend to enter the realm of high policy debate, are opposed on principle and, often as not, become political footballs. Less fanfare may produce more results.
2. The character of the industry which is the presumed beneficiary of the program is central to its potential for success. The structure of the industry must lend itself to taking advantage of the program's results and the leaders of the industry must be interested in and not opposed to the program. Government-industry ties need to be based on trust and perception of mutual benefit.
3. Careful attention needs to be given to the balance between user needs and the technical and institutional capabilities of the R&D institutions in designing programs. The programs need to be built on strength while yielding results that can be put to use in commercial applications.
4. Programs of generic applied research seem to be a particularly fruitful avenue of collaboration. The precise nature of such generic research may vary from one field or area of application to another, however, and the conduct of such research in and of itself is not sufficient to assure that it is used productively in the appropriate industry.

Tassey (1985), in discussing lessons learned from the Experimental Technology Incentives Program (ETIP), emphasized the need to take into account the dynamics of the market place and the interactions of the

relevant factors when planning government policies and programs intended to influence the rate and direction of industrial innovation. He also stressed the importance of maintaining flexibility to make mid course adjustments to fine tune policies under investigation.

Noll (1985) noted that the government has undertaken three types of R&D programs: (1) those aimed at improving the quality or reducing the costs of the goods and services the government itself uses, (2) those aimed at contributing to the general technological base of the society by supporting basic research in science and technology, (3) those aimed at producing new commercial technology for a specific industry or sector of the economy because that sector is especially weak at innovating on its own.

Two reasons, according to Noll (1985), are usually given for government involvement in R&D programs: First, "R&D is desirable because it promotes economic growth, strengthens national defense, and contributes to national prestige, not to mention that it creates new knowledge that may be a valued end in its own right." Second, "R&D tends to be insufficiently undertaken by the private sector if left to its own devices." He also observed, however, that there are serious political barriers to the efficient implementation of R&D programs that must be taken into account. He suggested that, from a political standpoint, the most attractive R&D programs will have the following characteristics:

- They can be readily connected to one of the very few salient political issues on which elections normally turn: the state of national defense or, in the mid-1970s, the rapid increase in the price of energy.
- They can easily be spread around to all the important components of the contracting industry, either because the industry is concentrated (so that a few contracts and subcontracts do the job), or by fragmenting the program in an unconcentrated industry into numerous small projects (e.g., agricultural extension, and basic research grants to universities).
- They promise relatively short-term payoffs in politically visible benefits and expenditures to politically important constituencies.
- They are unlikely to produce an embarrassing failure that will lead to investigations and scandal; hence to the maximal extent the government itself will have control over the decision to use the new knowledge or to declare it a success.

Finally, Noll (1985) describes the ideal federal R&D program:

> The most attractive R&D, then, is short-term in nature, is directed at the production of government goods (e.g, defense or space exploration) so that it can lead to utilization regardless of the shortfall in performance or overrun in costs, is addressed to a widely accepted, generally uncontroversial national objective, and can be

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undertaken without substantially altering the distribution of market advantages in the private economy. Least attractive are programs that address unsensational, long-term goals (e.g., long-term economic growth), that require very large contracts for a relatively small fraction of an industry, that are not only uncertain in terms of results but that can end in obvious failure, and that are unlikely to produce tangible evidence of success for a long period of time.

CONCLUSIONS

With currently-available statistics and analytical tools, it is impossible to determine in terms of macroeconomics how federal R&D programs affect the overall economy. Most economists seem to believe intuitively that such programs are beneficial, however they cannot prove it. Most also believe that federal R&D expenditures do not cause a decrease in private R&D investments and that while an increase in federal R&D causes salaries of researchers to rise, the salaries tend to stabilize in a few years when the supply of researchers catches up with demand.

The results of previous and ongoing federal R&D programs are varied. Some programs have been highly successful, others have failed. Whether a program succeeds or fails seems to depend more on political and nontechnical considerations than technical ones. Thus, if a federal construction-related R&D program is carefully crafted to account for the political factors, it should have a good chance of succeeding.

The keys to a successful federal R&D program are the following:

- Involve representatives of all segments of the building community in the process of formulating the program, and design the program to address a broad spectrum of needs. For example, the concerns of federal agencies that procure buildings as well as those of agencies that are interested in broader issues should be recognized.
- Concentrate on generic (nonproprietary) problems, opportunities, and issues; avoid involvement in the design, development, manufacturing, or marketing of proprietary products or concepts.
- Try to get a long term commitment to the program from Congress.
- Design the program to generate numerous small payoffs over an indefinite period of time; do not promise big results quickly.

- Design the program to cover the full spectrum of research projects, from the discovery of new basic knowledge to the development of better methods of disseminating known technology.
- Design the program to permit researchers and research organizations from various segments of the industry to participate.
- Include a mechanism for promoting continuous two-way communications between users of technology (e.g., owners, contractors, designers) and researchers. R&D is of little value if it does not address real problems and important issues and if the results are not widely disseminated.
- Keep the size of the program large enough to ensure that many members of the building community can be involved and that the results of R&D will have widespread impact, but not so large that it becomes a target for budget cutting.
- Find a mechanism for funding the program that will help ensure its stability and continuity.

7

SUMMATION AND RECOMMENDATIONS

The committee's investigation has shown that the U.S. construction industry is a major element of the U.S. economy, that the federal government has a legitimate interest in construction because of the size and importance of the industry and because the government is a major construction consumer, that the industry has a serious productivity problem, that R&D can help improve productivity, and that construction-related R&D investments have been inadequate in the United States.* It has also shown that federal R&D programs aimed at promoting technological development can succeed if they are properly planned and executed.

The committee also found that although federal agencies already perform or fund a considerable amount of construction-related R&D, most of it appears to be concerned with the design of federal facilities, and it probably contributes little to construction productivity. Consequently, the current programs do not effectively compensate for the lack of R&D by other elements of the construction community. Even though the federal government would benefit from lower costs through R&D-generated increases in construction productivity, it is probably unrealistic to expect operational agencies to take the lead in performing or funding R&D of a generic nature. Agencies are under almost constant pressure to reduce budgets and expenditures, and most are unwilling to try to defend requests for funds that are not clearly related to their missions.

Finally, the committee found no reason to believe that the private sector will substantially increase its investment in R&D. Although a construction-productivity problem has been recognized and discussed for many years, the amount spent on R&D by most segments of the construction community has remained low. It seems unlikely that the factors causing this situation (e.g., the attitudes of those involved or the

*It should be emphasized that the term R&D, as used here, includes investigations and studies dealing with management, administration, cost control, and other nontechnical subjects. Indeed, some committee members believe that R&D in nontechnical areas are likely to produce more productivity gains for construction than technically-oriented R&D.

structure of the industry or both) will change. It is possible that some kind of special tax incentive might be devised to encourage private investment in construction-related R&D. However, tax incentives for R&D investments in all segments of industry have existed for many years, and they have not yet resulted in any large investment in construction R&D. Furthermore, the enactment of additional incentives for the construction industry seems unlikely.

Thus, a significant increase in construction-related R&D, especially R&D aimed at improving construction productivity, will probably occur only as a result of some direct, congressionally mandated federal action. Given the seriousness of the construction industry's productivity problems, the committee is convinced that a substantial increase is needed in federal funding for construction-related R&D, especially R&D aimed at improving productivity. Such an increase can be justified on the grounds that both the national economy and the federal government itself would benefit from lower construction cost. The committee is also convinced that a new federal construction R&D program would have a high probability of producing worthwhile results if it is organized in accordance with the guidelines presented in Chapter 6. Therefore, on the basis of its findings and conclusions, the committee makes the following recommendations.

1. The Congress should formally acknowledge the need for federal leadership in conducting, funding, and coordinating general construction-related R&D, just as it has in agriculture, medicine, transportation, and many other fields. This acknowledged leadership should be reflected in federal programs.

2. In order to ensure the stability of the program, the Congress should consider methods of funding a strong federal R&D program that would provide stability and continuity. Numerous options are available. Congress might consider, for example, providing multi-year authorization and appropriation for the program, establishing a program trust fund of some type, or funding the program through an automatic surcharge on all federal construction appropriations--like the approach that has been used for many years to fund highway research and planning.*

3. In order to ensure that a broad spectrum of construction R&D needs are met, the Congress should provide for the distribution of program funds to the various federal agencies that have construction-related responsibilities; for example, some funds could be allocated to

*In FY 1984 the federal government spent a total of almost $44 billion on construction (see Chapter 3). If, for example, a 1.0 percent surcharge had been added to each construction appropriation that year, approximately $440 million would have been generated for construction related research. Inasmuch as federal agencies actually spent about $220 million in FY 1984 on construction R&D, the 1.0 percent surcharge would have increased the FY 1984 budget by only $220 million.

the agencies that are responsible for procuring federal facilities for R&D on the design and construction of such facilities; some funds could be allocated to agencies like the National Bureau of Standards and the National Science Foundation for generic R&D for the entire construction community; and some funds could be allocated to information-generating agencies like the Bureau of the Census and the Bureau of Labor Statistics for the development and publication of more accurate construction statistics.

4. In formulating the program, the Congress should provide a mechanism to ensure that the construction R&D activities of the various federal agencies are coordinated and that information and technology produced through such activities are widely disseminated. To accomplish this, the Congress might consider giving a particular agency overall responsibility for managing the program and distributing R&D funds to other agencies. Alternatively, Congress might permit the various agencies to manage their own R&D programs, but require them to participate in a cooperative, coordination body (either public or private) that would do for construction R&D what the National Research Council's Transportation Research Board has done for highway research for many years. (See Appendix C for a discussion of federal highway research programs and the Transportation Research Board's role in those programs.)

APPENDIX A

PRODUCTIVITY INFERENCES FROM COST ESTIMATING DATA

Some members of the committee objected to relying too heavily on national statistics to form judgments on construction productivity. The true measure of productivity, they believe, is what occurs at the job site. Usually, however, contractors who keep productivity data that would shed light on the question are reluctant, for competitive reasons, to reveal such data. The committee, therefore, sought other sources of data on on-site productivity.

For more than 10 years, the Robert S. Means Company has included estimates of the daily output of crews ordinarily employed to perform various tasks in its widely-used annual construction cost estimating manual. The committee believed that the Means' estimates of the daily output of construction crews would give an accurate indication of the productivity of construction workers at the task level and that productivity trends in construction might be obtained by comparing the output of selected construction crews over a period of years. The use of cost estimating guides to develop productivity statistics previously had been suggested by Dunlop (1972).

The committee took this approach and compared the productivity of construction crew members performing 30 different tasks in 1975 and 1985, using data published in Means (1974, 1984). The tasks were selected randomly but not scientifically. Results are presented in Table A-1. The last column indicates the percentage change in output over the 10-year period.

The results show great variation in productivity during the period for the 30 tasks investigated. Specifically, output per crew member increased for 13 tasks, decreased for 11 tasks, and remained unchanged for 6 tasks. This suggests no clear trend in construction productivity, either up or down, between 1975 and 1985.

TABLE A-1 Output of Construction Workers Performing Various Tasks: 1975 versus 1985

Task[a]	Unit[a]	Daily Output Per Crew Member		Percentage Change In Output
		1975	1985	
Clear medium trees to 10-in diameter; cut and chip	Acre	0.095	0.133	+40
Core drilling (4-in diameter), reinforced concrete slab up to 6-in thick	Each	4.9	34	+594
Bulk excavation, medium earth, self propelled scrapers, 15 Cu yd capacity, 1500-ft haul	Cu yd	300	457	+52
Hand excavation, pits to 6-ft deep, ordinary soil	Cu yd	8	8	0
Dozer backfilling, bulk, up to 300-ft haul, compacted, 6-in to 12-in lifts, vibrating roller	Cu yd	367	533	+45
Install, base course, select gravel, 6-in deep	Sq yd	277	750	+171
Install concrete paving, 6-in thick, with mesh, not including base, joints, or finish	Sq yd	182	182	0
Sodding in East, 1-in deep, on level ground	Sq yd	78	166	+114
Install concrete slabs, 4-in thick, elevated, including finish, but not forms or reinforcing	Sq yd	214	384	+79
Install brick masonry veneers, single wythe, standard size red face brick, running bond	1,000 bricks	0.25	0.27	+9
Install concrete block partitions, 6-in thick, sand aggregate, not reinforced, regular 8-in x 16-in block	Sq ft	61	58	-5
Install structural steel space frame, 5-ft modular, 4.5#/sq ft	Sq ft	150	84	-44
Install structural steel for offices, hospital, etc., 3 to 6 stories, bolted	ton	00.875	0.9	+3
Rough carpentry, light framing, 8-ft high wall, 2-in x 4-in studs	1,000 board ft	0.35	0.46	+31
Rough carpentry, heavy framing, 6-in x 10-in beams	1,000 board ft	0.55	0.55	0
Install built-up roofing, asphalt and gravel, 4-ply roofing on flat roof	100 Sq ft	4.67	2.86	-39
Install factory and industrial rolling steel service doors, manual, 10-ft x 10-ft high	Each	0.9	0.7	-22
Install glass plate, 1/2-in thick, clear, plain	Sq ft	30	27.5	-8
Install dry wall, standard gypsum plaster board, 1/2-in thick, nail to studs	Sq ft	900	900	0

Table A-1 cont.

Install partition walls, 5/8-in gypsum dry wall, taped both sides, on 2-in x 4-in wood studs	Sq ft	127.5	150	+8
Install ceramic tile floors, natural clay, random or uniform	Sq ft	100	091.5	-9
Install suspended ceiling, metal pan with acoustic pad, including standard suspension system but not 1-1/2-in carrier channels	Sq ft	205	205	0
Interior painting on plaster or drywall, walls and ceilings, roller work, primer + 1 coat	Sq ft	1330	1125	-15
Install 4-in diameter cast iron soil pipe, lead and oakum joints, fittings 10-ft on center on hangers	lin ft[a]	22	22	0
Install 3-in diameter plastic drain, waste and vent pipe, including fittings and 3 hangers/10-ft.	lin ft	25.5	26.5	+4
Install 5-ft cast iron bathtub, recessed, shower and curtain,	Each	2.2	2.0	-9
Install boiler insulation, 1-1/2-in calcium silicate, with 1/2-in cement finish	Sq ft	34	25	-26
Install 4-light recessed flourescent troffers 48-in x 24-in	Each	3.5	4.7	+34
Install steel duct work, 1000 to 2000 lb, including fittings and joints, but not insulation	lb	90	88	-2
Install electric cable, non metallic, with two #12 copper wires and ground	lin ft	383	250	-35

[a]Abbreviations: cu yd. cubic yards; ft, feet; lin ft, linear feet; lb, pounds; sq ft, square feet; sq yd, square yards.

SOURCE: Means (1974, 1984).

APPENDIX B

CONSTRUCTION R&D ACTIVITIES OF FIVE FEDERAL AGENCIES

During the study, five federal agencies briefed the committee on their R&D activities: the Army Corps of Engineers, the Naval Facilities Engineering Command, the Air Force Directorate of Engineering and Services, the Office of Construction of the Veterans Administration, and the National Science Foundation. The highlights of those briefings are summarized below. The information is neither official nor exhaustive.

The Corps of Engineers operates eight laboratories concerned with construction. Five laboratories concerned with water resources are located at the Waterways Experiment Station at Vicksburg, Mississippi. The other laboratories are the Construction Engineering Research Laboratory, Champaign, Illinois; the Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire; and the Engineering Topographical Laboratory, Fort Belvoir, Virginia. In FY (fiscal year) 1985 the Corps expects to spend approximately $42.7 million for research, development, testing, and evaluation (RDT&E). Of this total, approximately $27.6 million is for logistics- and combat-related research, $2.2 million is for work for the Department of Defense and other agencies (mostly related to mapping), and $12.9 is for "base support", which includes work related to environmental quality, facilities engineering, installation support, and facilities development in such areas as pavements and foundations, construction technology, construction management, and planning and design.

The Air Force conducts research, development, testing, and evaluation (RDT&E) related to the maintenance and repair of Air Force facilities at Tyndall Air Force Base in Florida. The Air Force expects to spend approximately $33 million on such RDT&E in FY 1985. The Air Force program is divided into two parts: civil engineering ($18.8 million) and environmental quality ($14.2 million). Civil engineering is subdivided as follows: $6.1 million for research, $6.3 million for development, and $6.4 million for testing and evaluation. In the civil engineering portion of the program, work is carried out in such areas as fire protection, contingency lighting, pavement construction, and bomb crater repair. The environmental quality portion of the program includes work on hazardous wastes disposal and combustion.

The Navy conducts facilities-related RDT&E at Port Hueneme, California. The Navy FY 1985 budget for such work is approximately $4 million, of which $1 million is for research and development and $3 million is for testing and evaluation. Among the topics being investigated are concrete durability, roofing, and quality control. Unlike the Air Force, the Navy does not include projects related to environmental quality and energy consumption in the RDT&E budget for facilities.

The Veterans Administration (VA) spends approximately $1 million/year on facilities-related research and development. All such research is performed under contract; the VA has no facilities laboratory. Topics investigated in 1985 included reducing VA construction costs, smoke control, hot water demand, fire tests of floor and ceiling components, and operations and maintenance manuals for VA facilities.

The National Science Foundation (NSF) has no laboratories. Its primary mission is to support R&D in academic institutions. In FY 1985 the NSF expected to distribute approximately $4.4 million in the form of grants to academic institutions for research on structural systems, building systems, and the construction process.

APPENDIX C

SOME FREVIOUS GOVERNMENT EFFORTS TO PROMOTE TECHNOLOGICAL DEVELOPMENT

In connection with its investigation of the feasibility of federal agencies taking action to promote, fund, or conduct R&D to improve productivity in the construction industry, the committee reviewed the results of previous and in some cases ongoing government efforts to promote technological development in various industries, including the construction industry. Among the programs reviewed were: Operation Breakthrough, the Civilian Industrial Technology Program, the Industrial Energy Conservation Program, the National Shipbuilding Research Program, the Experimental Technology Incentives Program, the Research Applied to National Needs Program, the U.S. Department of Agriculture's science and education programs, the federal highway research programs, and the Modular Integrated Utility System project. These particular programs were selected for review because they represented a cross-section of federal technology-development programs and because critiques of them had been published.

OPERATION BREAKTHROUGH

In accordance with Section 108 of the Housing and Urban Development Act of 1968, the Department of Housing and Urban Development (HUD) embarked in mid-1969 on a major project called Operation Breakthrough. This effort had as its primary objective the establishment of mechanisms to mass-produce and mass-market housing for families at all income levels, but particularly for those of low and medium incomes.

In addition to its primary objective, HUD established a number of secondary objectives for the Breakthrough program, including stimulating the modernization and broadening of the housing industry, increasing participation by state and local governments in planning and site aggregation, waiving or removing constraints to the introduction and use of tested and proven innovations, introducing new organizational concepts and management techniques, encouraging identification and development of performance standards for evaluation of innovations, developing an ongoing testing and evaluation mechanism, and developing

techniques for increased participation by consumers and community groups.

At HUD's request, the National Research Council (NRC) established the Advisory Committee to the Department of Housing and Urban Development (ACHUD) in June 1969. ACHUD's primary mission was to provide guidance to HUD on the technical aspect of Operation Breakthrough. In 1974, when its work was completed, ACHUD prepared a critique of Operation Breakthrough (Advisory Committee to the Department of Housing and Urban Development, 1974).

ACHUD noted that while the objectives of the program were not fully achieved, Operation Breakthrough was of some value in that it helped advance the industrialization of housing construction (particularly with regard to components), helped broaden the housing industry, increased the participation and awareness of state and local governments in housing, encouraged removal of some constraints on the use of innovations, and promoted the application of performance criteria. ACHUD also noted, however, that the program was very costly ($72 million) and that numerous difficulties were encountered, many because the managers of the program set unrealistic goals and schedules that could not be met. In its report, ACHUD made an obvious effort to be fair to the planners and managers of Operation Breakthrough, but there was a clear implication that ACHUD considered the program largely a failure.*

CIVILIAN INDUSTRIAL TECHNOLOGY PROGRAM**

In 1962 the Department of Commerce requested congressional appropriations for a proposed Civilian Industrial Technology Program (CITP), which had three purposes:

1. to foster innovation in such lagging industries as building and textiles,
2. to study the information needs and state of technology in other industries, and
3. to create an industry-university service to diffuse information and provide technical aid.

The CITP was proposed as a method of providing the benefits of R&D to areas of the economy that were perceived as technically backward and unable or unwilling to fund the necessary R&D themselves. The presumption was that a federal program was needed to fill the gap. Although funds were provided for a short time for the textile technology portion of CITP, the building technology portion of the program was never funded due to the vehement opposition of some leaders of the building industry. This opposition eventually caused the demise of the entire program.

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*One benefit of Operation Breakthrough was that it destroyed some myths about the advantages of industrialized housing.

**Information on this program is primarily from Nelkin (1971).

Nelkins (1971) noted that the building industry was included in the CITP because--in spite of the availability of new materials and new means of mass production--it was believed that the rate of change in construction methods would not be sufficient to meet the increasing need for adequate shelter at reasonable cost. The proponents of the program believed that construction costs could be reduced through more R&D and that the proposed federal program would provide the needed R&D. Opponents of the program argued, however, that there was no evidence that R&D would produce worthwhile results that would lower the cost or improve the quality of housing. Nelkins suggests that CITP opponents were motivated by political conservatism and concern that federally sponsored technological innovation would disrupt the building industry.

Eventually, the CITP evolved into a much more modest effort known as the State Technical Services Program (STS), which was approved by Congress in 1965. Instead of supporting R&D, STS sought merely to deliver technical information, using state and local agents and other means to be developed jointly by industry, universities, and the federal government. Teich (1985) noted that without the kind of strong ties to specific research programs that supported the Agricultural Extension Service, the STS program never really took hold. It was terminated by Congress in 1969.

INDUSTRIAL ENERGY CONSERVATION PROGRAM

The Industrial Energy Conservation Program of the Department of Energy was initiated in the mid-1970s on the premise that investments in energy conservation by industry were being constrained by uncertainty regarding both economic factors (e.g., fuel prices, fuel availability, taxes, and tax credits) and technical considerations (i.e., uncertainty about whether various proposed conservation measures actually would work). The program was intended to help eliminate such uncertainty. In particular, the following areas were singled out for study under the program:

- Existing but underutilized technologies whose implementation could be stimulated by an identifiable federal action.
- New technologies from R&D that provide advanced concepts with proven economic and technical feasibility in industrial operating environments.
- Economic incentives, such as tax credits, which provide economic rewards for industrial actions in the national interest.
- Other actions that have been legislated to establish requirements and motivation for industry.
- A market-oriented commercialization effort to ensure accelerated transfer of technology for specific industrial end-users and the maximum implementation of these technologies.

In 1980 the Department of Energy asked the National Research Council (NRC) to form a committee to evaluate the Industrial Energy Conservation Program. The NRC Committee on Assessment of the Industrial Energy Conservation Program (1981) found that, with some exceptions, the program included a "well balanced mix of projects," eight of which had been successfully completed and were producing savings of more than $60 million/year. By 1984, the detailed objectives of the program had been changed, though the overall goal remained the same. Therefore, the Department of Energy asked the NRC to form another committee to again critique the program. The findings of the new Committee on Industrial Energy Conservation (1985) were similar to those of the first committee.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

Authorized by the Merchant Marine Act of 1970, the National Shipbuilding Research Program is a cooperative venture between the shipbuilding industry and the Maritime Administration (MarAd). It provides financing and management of research projects to improve the productivity of U.S. shipyards and their competitiveness in the world shipbuilding market. The program, initiated in 1971, is financed by both industry and government and provides for industry involvement in technical management and execution through the Ship Production Committee (SPC) of the Society of Naval Architects and Marine Engineers. The SPC collaborates with MarAd in the management of the program, especially to set program priorities, assign responsibilities for projects, provide technical direction, and assist in demonstrating program results.

Individual projects are developed by panels of the SPC. The panel structure is flexible--panels are added or abolished as the SPC determines the need. Lead shipyards provide an administrative and technical base for each panel's activities. Panel activities are overseen by a full-time project manager, an employee of the base shipyard. The salaries and expenses of the project managers are paid jointly by the lead yard, MarAd, and the Navy.

The NRC Committee on Navy Shipbuilding Technology (1982) reviewed the program in connection with its 1981 study of productivity in Navy shipyards. The committee found that by 1982, 76 major projects had been completed under the program, and 18 more were in progress. The committee also found that "the program has stimulated pragmatic, results-oriented projects, fostered technical communication and exchange among shipyards, enhanced the incorporation of productivity improvements into shipyards, and promoted communication of shipbuilding industry requirements to industrial suppliers." The committee concluded that the program "has resulted in productivity-related research and development in the shipyards and a growing awareness on the part of management of the value of such activities."

EXPERIMENTAL TECHNOLOGY INCENTIVES PROGRAM

The Experimental Technology Incentives Program (ETIP) was created at the National Bureau of Standards in 1972 as a means for the federal government to help increase innovation in civilian technology. Under ETIP, various federal agencies were expected to cooperate in exploring ways in which technological development could be stimulated though changes in the policies and procedures of the federal government. The emphasis in ETIP was on R&D regarding government policies. In practice, ETIP R&D centered on procurement policy, regulation, and economic assistance policies. Procurement policy projects were carried out with high volume purchasing agencies, particularly the Federal Supply Service (FSS). A number of procurement mechanisms were tried, including life-cycle costing, value incentive clauses, and performance specifications. Regulatory projects dealt with federal regulations concerning a wide range of regulated industries, including the pharmaceutical, railroad, transport, and communications industries. Economic assistance projects dealt with R&D, small business, capital formation, and venture capital market policies.

The ETIP program was reviewed in 1977 by the NRC Evaluation Panel for the National Bureau of Standards (1978), at which time the ETIP staff numbered 17 and had an annual budget of about $3.2 million. The panel found that the program was both effective and important and that the potential for future benefits was extremely good. Subsequently, several projects were successfully completed. Nevertheless, ETIP was terminated in 1982. Tassey (1985) cites several reasons: First, internal management problems, which resulted in a shift in emphasis away from pragmatic projects toward more research oriented studies (reflected in program name change to the Center for Field Methods); second, lack of support by the National Bureau of Standards and the Department of Commerce; third, the perception that the program lacked an overall strategy for integrating individual experiments into an effective, broad plan.

RESEARCH APPLIED TO NATIONAL NEEDS PROGRAMS*

The original 1950 charter of the National Science Foundation (NSF) defined the NSF mission as basic research. Almost from the beginning, however, some engineering research and applied research was undertaken, and in 1968 the NSF charter was modified to officially authorize these areas of research. The change also helped the NSF deflect criticism from some members of Congress and the public that it only sponsored esoteric and useless research.

NSF's first response in 1969 to the change in its charter was to form a program called Interdisciplinary Research Relevant to Problems

*Information on this program is primarily from Science Applications Task Force (1977).

of Our Society (IRRPOS). The Research Applied to National Needs (RANN) program was an outgrowth of IRRPOS, created during the preparation of the FY 1972 NSF budget with encouragement from The Office of Management and Budget. An ad hoc Task Force on Research Applied to National Needs was formed to integrate some existing NSF problem-oriented units into the new program. The proposed FY 1972 budget of $43 million included all of IRRPOS, plus earthquake engineering from the Engineering Division, and weather modification and other interdisciplinary or problem-oriented activities from various parts of the NSF. RANN received formal approval in March 1971 when the Research Applications Directorate was formed. Its mission was to identify "national needs" not being addressed by existing research agencies; to fund both basic and applied research relevant to the national needs; and to obtain utilization of the funded research.

Several advisory groups helped develop the early RANN programs and objectives. Two subcommittees of the Committee on Public Engineering Policy (COPEP) of the National Academy of Engineering were highly influential. The first subcommittee concentrated on criteria for RANN programs, and the second (in 1973) examined a number of possible issues and suggested those that should take priority. New programs particularly stressed energy. As a result, the budget grew to over $130 million by FY 1975, when most of the energy work was transferred to the Energy Research and Development Administration (ERDA). Later, other RANN projects were transferred to other agencies; e.g., the fire safety research program went to the Department of Commerce in FY 1976, and the Chesapeake Bay Project went to the Environmental Protection Agency in FY 1977.

The fiscal year 1978 budget request, $78 million, focused on the following major areas: resources ($11.5 million); environmental issues ($34.5 million); productivity ($23.0 million); exploratory research and technology assessment (i.e., research to provide better understanding of the long-range social, environmental, and economic impact of new technology) ($2.0 million); and intergovernmental science and public technology (i.e., integration of science and technology into the policy planning activities of state and local governments) ($7.0 million).

The following criteria were used in selecting problems for RANN support:

- The problems should have national importance.
- The payoff of research is expected to exceed significantly the costs of research on the problem.
- The leverage of science and technology on the problems is substantial.
- The research efforts will be timely and scientifically up-to-date.
- Academia, industry, and the federal government are able to mount a successful research program.
- There is a need for federal action, in that normal market forces are not likely to generate the required research on the problems.

- The problems to be addressed by RANN either overlap the boundaries of several mission agencies, fall between the boundaries of the charters of mission agencies, or meet the longer range needs of one or more agencies.

The RANN program was reviewed several times during its life; e.g., by the General Accounting Office (GAO); the Committee on Social and Behavioral Sciences of the NRC, the Research Triangle Institute, and the NSF Science Applications Task Force. The program got mixed reviews. The GAO report recommended a number of administrative changes, which were made. The NAS report called the RANN program "a useful component of the federal government's support of applied behavioral and social science research" but rated the program as "highly variable in quality." The members of the NSF Task Force were split. Several members felt that RANN constituted the most successful and cost-effective broad applications program ever mounted by the government. Other members felt that RANN's overall effectiveness had not been demonstrated. Most of the members agreed, however, that many useful programs had been conducted under RANN; e.g., energy research, fire safety research, earthquake engineering, truck-drag research, automatic optical pattern recognition research (for production work), work on environmental law and uniform state statutes, and research on technological aids for the handicapped.

The RANN program ended on September 15, 1977. In an unpublished paper, McNinch (1984) noted that during the 6-1/2 years the program lasted, $468.3 million were distributed as follows: 48 percent to universities and colleges, 34 percent to industry, 16 percent to nonprofit organizations, and 2 percent to state and local governments. The average RANN award was $72,000. McNinch attributed the demise of the program to the fact that "RANN never enjoyed the support of NSF's basic research clientele in universities"; some personality conflicts, and the fact that the interdisciplinary, problem-oriented organizational approach used with RANN was "totally foreign to the basic research community." The opposition of the basic research community to RANN, McNinch says, was prompted by fear that NSF support for pure research would be jeopardized by RANN. Ironically, the program's considerable support in Congress may have contributed to RANN's death by increasing the concern of basic researchers about continued funding for their own work. Finally, McNinch observed that even though the RANN program was terminated, many of the RANN projects have been continued, some as part of other NSF programs and some in other agencies.

U.S. DEPARTMENT OF AGRICULTURE'S SCIENCE AND EDUCATION PROGRAMS*

Although the act that established the U.S. Department of Agriculture (USDA) in 1862 said little about research, the House Committee on

*Most information on this program is from the United States Government Manual 1984/85 (General Services Administration, 1984).

Agriculture clearly had research in mind. Consequently, one of the first acts of the new Department was to establish a 40-acre experimental farm on the Mall in Washington, D.C., and USDA has been heavily involved in R&D and education ever since. Currently, five elements carry out the science and education activities of the USDA: The Agricultural Research Services, the Cooperative State Research Service, the Extension Service, the National Agricultural Library, and the Office of Grants and Program Systems.

The Agricultural Research Service (ARS) administers a basic, applied, and developmental research program in animal and plant protection and production; the use and improvement of soil, water, and air; the processing, storage, and distribution of farm products; and human nutrition. Research activities are carried out at 136 locations nationwide, in Puerto Rico, in the Virgin Islands, and in 8 foreign countries. Much of this research is conducted in cooperation with state universities and experiment stations, other federal agencies, and private organizations.

The Cooperative State Research Service (CSRS) distributes federal funds for agricultural research performed by the state agricultural experiment stations and by various schools around the country. Grants are awarded on the basis of research proposals submitted by state agricultural experiment stations and other institutions.

The Extension Service is the educational agency of the USDA. It is one of three partners in the Cooperative Extension System; state governments, through their land-grant universities, and county governments are the other partners. All three share in financing, planning, and conducting the Extension's educational programs. Created by the Smith-Lever Act of 1914, the Extension Service helps the public learn about and apply the latest technology developed through USDA research and other sources. Major areas of assistance are agricultural production, marketing, natural resources, home economics and human nutrition, 4-H Club youth development, rural development, and related subjects. State specialists, located in nearly every county nationwide, provide technical assistance to county and area organizations. Area and county agents work directly with individuals, families, and groups to help them apply the most recent proven technology.

The USDA also operates the National Agricultural Library, which is the largest agricultural library in the United States, and administers a program of competitive extramural grants to promote research in food, agriculture, and related areas. These grants are awarded to state agricultural experiment stations, colleges and universities, other research institutions and organizations, federal agencies, private organizations or corporations, and individuals.

The R&D activities of the USDA have been reviewed on numerous occasions in past years by Congressional committees, the GAO, and committees of the NRC; many changes have resulted from these reviews. In 1981 a comprehensive critique of USDA R&D and education programs was conducted by the Office of Technology Assessment (OTA) (1981). OTA found some problems, such as friction between state and federal re

search units that has resulted in the loss of an enormous amount of time and effort, and extra layers of administration resulting from various USDA reorganizations. The OTA also expressed concern whether USDA could meet the future agricultural research needs of the country due to the lack of well-defined long-range goals and a decline in funding for R&D. In general, however, the OTA gave the USDA R&D program high marks and credited it with making the United States the preeminent agricultural nation in the world.

Weaver (1985) reviewed and analyzed the efforts of several economists who calculated the return on federal investments in agricultural R&D. Nearly all of the economists reviewed had reported a positive return. Weaver noted, however, that such calculations are subject to dispute and he cautioned against accepting them uncritically.

FEDERAL HIGHWAY RESEARCH PROGRAMS*

Federally sponsored highway research antedates the automobile age. In 1883 the USDA established the Office of Road Inquiry to investigate the best methods of road-making and to help disseminate this information. In 1900 a federal laboratory was created to evaluate highway materials. The desperate need for better roads and better road-building techniques was obvious. Europeans visiting North America at the time were struck by the excellence of the railroads and the inferiority of the roads.

Over the years, the federal government has maintained a strong interest in highway research. The Highway Act of 1921 authorized sustained support for highway research, and the Hayden Cartwright Act of 1934 provided that 1.5 percent of annual road appropriations to any state could be used for surveys, plans, or engineering investigations. The Federal-Aid Highway Act of 1944 broadened the uses of this 1.5 percent to include planning and research. The Surface Transportation Assistance Act of 1982 broadened the funding base for each state's federal-aid highway apportionment, and the planning and research authorization increased proportionately. As a result, research projects roughly doubled from 1982 to 1983 (from approximately 300 to 600 projects).

The $70 to $75 million that the United States spends annually on highway research is disbursed through a variety of programs. The Highway Planning and Research (HP&R) Program is by far the major source of support for highway research. Each state receives HP&R funding in the amount of 1.5 percent of its federal-aid highway apportionment. In addition, some states elect to receive 0.5 percent available for urban highway planning and research activities. State highway and transportation departments can divide HP&R money between planning and research as they see fit. Usually, about 15 to 20 percent of HP&R funds is

*Most information is from the Transportation Research Board, (1984).

spent for research, but some states spend as much as 55 percent for this purpose. State-sponsored research in the HP&R program may or may not be included in the Federally Coordinated Program of Highway Research and Development (described below under Federal Highway Administration). Approximately $20 million of the $30 million that states spend each year on research (excluding the $4.4 million allocated for the National Cooperative Highway Research Program, discussed below), comes through the HP&R program. The remainder is state matching funds. States also spend about $5 million/year of their own funds on research, independent of any federal program or matching funds.

The National Cooperative Highway Research Program (NCHRP) emerged not long after construction began on the Interstate Highway System, when many states began to experience similar new problems related to the design of that system. Instead of attempting to deal with the problems individually in each state, the states arranged through the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the Transportation Research Board of the NRC to combine resources in a new research program created to address common problems. Since NCHRP was organized in 1962, 358 projects have been completed and 100 syntheses published. The program operated at a level of about $4.5 million/year for many years; however, funding increased to about $6.8 million/year as a result of the Surface Transportation Assistance Act of 1982.

The FHWA funds a broad array of research conducted by private contractors, consultants, universities, or FHWA staff. Many staff studies are continuing efforts in major research areas, but a significant portion of the research effort is in quick response to particular operational problems and preliminary investigations of new problems. Although FHWA's research expenditures have been roughly consistent over the past 5 years, inflation has substantially reduced the size of this program. A principal part of the FHWA research effort is the Federally Coordinated Program of Highway Research and Development (FCP) established in 1971 to coordinate federal and state activities. Recognizing that the states control the larger research efforts and also possess much of the talent needed to perform effective research, the FCP works with the states to coordinate four programs that are largely derived from federal funding--NCHRP and HP&R, discussed above, and the FHWA administrative contract and staff research programs. Virtually all work in the FHWA contract and staff research programs and approximately 70 percent of work in the HP&R and NCHRP programs are included in the FCP.

The National Highway Traffic Safety Administration (NHTSA) funds and conducts highway-related research on specific safety problems, in addition to a substantial program of upgrading accident data records systems. Some $2 million of research funded and performed by NHTSA is directly applicable to the design and operation of roads and streets.

The Office of University Research of the U.S. Department of Transportation funds highway transportation research projects through a special grant program. The Urban Mass Transportation Administration

(UMTA) has also funded highway research, particularly for urban street operations and transportation systems management techniques that directly relate to street design and operation. Policy research related to highways is performed from time to time by the Office of the Secretary of Transportation. Pavement-related research conducted by the Federal Aviation Administration (FAA) also can be applicable to highways. Recently, the Environmental Protection Agency and the Department of Energy funded staff and contract research in the general area of highway transportation, with particular emphasis on environmental impacts and energy conservation techniques.

Both the U.S. Army Corps of Engineers and the U.S. Forest Service undertake research applicable to highway transportation. Their research is usually directed to specific problems encountered in road construction and maintenance programs within their agencies. The Forest Service builds and maintains a 320,000-mile road system nationwide, adding approximately 10,000 miles each year. It is the fourth largest road system in the world, and annual road-related expenditures are approximately $750 million.

The Transportation Research Board (TRB) of the NRC was organized in 1920 (as the Highway Research Board) to help stimulate, correlate, disseminate, and perform highway research. (The name of the board was changed during the 1960s when the scope of its activities were broadened to encompass research in nonhighway modes and interactions between transportation and social, environmental, and economic issues.) TRB programs are carried out by some 270 committees, task forces, and panels comprised of more than 3,300 members from a wide range of scientific and technological disciplines. TRB is supported by state transportation departments, various administrations of the U.S. Department of Transportation, the Association of American Railroads, and many private companies and individuals.

MODULAR INTEGRATED UTILILTY SYSTEM PROJECT*

The Modular Integrated Utility System (MIUS) project was initiated in 1972 by the Department of Housing and Urban Development (HUD) in an effort to help reduce housing and energy costs. By definition, MIUS is a combined energy, utility, and waste disposal plant that is small-scale and highly integrated, and that can supply up to five services to a community: electricity, space and water heating, air-conditioning, solid waste processing, and waste water treatment.

In the MIUIS project, HUD joined with several other federal agencies and private organizations to assess the technical and economic feasibility of the MIUS concept, to carry out at least one full-scale real-life test of the concept, to assist the private sector in implementing MIUS, to identify relevant institutional constraints (e.g.,

*Most information is from Shostak (1979).

laws or public attitudes that would impede commercialization of MIUS), and finally, to monitor impacts after the concept had been implemented by the private sector.

The MIUS project was terminated in 1979. Two attempts had been made to build full-scale MIUS installations (one in New Jersey and one in Maryland) but neither was completed. However, a considerable amount of technical data was accumulated, and this was disseminated through a series of HUD-sponsored seminars and a MIUS handbook. Overall, the MIUS project must be considered unsuccessful. Nevertheless, the project probably helped lay the groundwork for the subsequent surge in cogeneration facilities and for the Intergrated Community Energy System Project of the Department of Energy.

Shostak (1979) attributes the difficulties of the MIUS project to: the failure of the project leaders to develop a constituency, the involvement of too many individuals and organizations in the planning process, the attachment of too much importance to the proposed demonstration installations (which could not be completed), and the insistence on private-sector involvement in financing the demonstration project.

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July 29, 1987

The Honorable Doug Walgren
Chairman of the Subcommittee on
Science, Research and Technology
Suite 2321, Rayburn House
Washington, D.C. 20515

Dear Mr. Walgren:

As a 1986 civil engineering master's graduate from the Massachusetts Institute of Technology, I was privileged to spend the past 12 months on a researchship in Japan where I worked with one of the "Big-5" Japanese general contractors - Ohbayashi Corporation.

During the researchship, considerable time was spent both in the R&D laboratory and field where various construction robots were being developed and extensively used. The enclosed report which I have prepared describes the most recent building technologies successfully developed and used by Japanese contractors and the direct correlation between this intensive R&D effort and overseas market penetration.

Please feel free to reproduce the report in any publications associated with construction R&D and new construction technologies which you think would be of interest.

Sincerely yours,
Peter J. Sherman

Enclosure

CONSTRUCTION R&D PAYS OFF!

A Technical Report Prepared

By

Peter J. Sherman, B.S.C.E., M.S.C.E.

Japanese Civil Engineering Intern (1986-87)

9801 Collins Avenue
Bal Harbour, FL 33154
July 28, 1987

ABSTRACT

The R&D laboratory and several of the most recently developed and successfully used construction technologies of Japan's "Big-5" general contractors are described. These technologies include the seismic or dynamic floor system which neutralizes the effects of earthquakes, robotic steel beam and column erectors, and a robotic concrete distributer. The system mechanics, performance record and cost and/or maintenance of each innovation has been described. The paper identifies the direct benefits being derived from such intensive R&D efforts: revenues generated by private consulting, licensing arrangements, and increased contract awards - both domestic and overseas. There appears to be a direct correlation between such intensive R&D expenditures and increased overseas market share as indicated by the recent emergence of Japanese contractors in the U.S. market, where they have been using their technical expertise in tunneling (shield pressure tunneling technology) and dams (deep diaphragm cut-off walls, roller compacted concrete dams) to underbid their American counterparts.

ACKNOWLEDGMENT

The author would like to express his deep appreciation to all of the members of the Ohbayashi Corporation Technical Research Institute, Special Construction Techniques Department, and Machinery & Equipment Department for supplying information on and photos of the R&D laboratory, the dynamic floor system, and the robotic beam and column erectors. Those individuals included Dr. Akiro Kohno (Director - R&D Laboratory), Messrs. Masayasu Higashi (Manager - R&D Planning & Administration Dept.), Okuda (Chief Engineer - Special Construction Techniques Dept.), Wakisaka (Manager - R&D Lab Robotics Section), and Toshio Nakamura (Machinery & Equipment Dept.).

The author would also like to thank Dr. Motoki Kondo (Director - Takenaka Komuten Technical Research Laboratory) and Mr. Iwao Uchizaki (Construction Equipment Unit - Takenaka Komuten R&D Laboratory) for their generous time and assistance in supplying information on and photos of several technologies including the Horizontal Concrete Distributer Robot.

CONSTRUCTION R&D PAYS OFF!

INTRODUCTION:

While it is well known that all of Japan's large general contractors and most middle-sized contractors perform their own "in-house" research and development, it is not so clearly realized just what direct benefits are being derived from such R&D expenditures. Construction R&D spending by Japanese contractors is generating income through increased contract awards, licensing arrangements and private consulting. But, perhaps most importantly, it is enabling Japanese firms to increase their overseas market share, particularly in the U.S.

The author* was privileged to spend the past year working in Japan with the Ohbayashi Corporation - one of the "Big-5" Japanese general contractors. During this training, considerable time was spent in the R&D lab. What follows is a description of Ohbayashi's lab and an account of several of the latest and most successful technologies developed in the labs of Ohbayashi Corp. and Takenaka Komuten, another "Big-5" firm.

THE LAB:

Nestled in the middle of a farming community outside Tokyo on 16 acres of land, the Ohbayashi Technical Research Institute (see Fig. 1) engages in the research of every kind of construction technology, including urban development, pollution prevention, energy conservation, development of nuclear-power facilities, energy storage, offshore structures and biotechnology-related matters. In all there are 16 departments within the laboratory. They include:

1. Civil Engineering (5 depts.): soils, tunneling, offshore structure technologies, etc.

2. Architectural Engineering (3 depts.): new materials and methods, robotization, etc. (See Fig. 2)

3. Structural Engineering (3 depts.): high rise design, nuclear power structures, base isolation structures, LNG tanks, etc. (See Fig. 3)

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* M.S.C.E., Massachusetts Institute of Technology, 1986

4. Soil and Foundations (1 dept.): earth retaining structures, deep foundations, etc.

5. Seismology and Vibration (1 dept.): vibration hazard prevention, design of machinery foundations, etc.

6. Environment Technology (1 dept.): solar energy, heat storage, clean air technologies, etc.

7. Acoustic Engineering (1 dept.): acoustical designs for studios, music halls, chapels; sound insulation, etc.

8. Chemical Engineering (1 dept.): properties of slurries used in excavation, soil stabilization, waste treatment, etc.

Established in 1948, the laboratory presently houses a staff of 300 members including 148 research engineers and 81 lab technicians who are supported by a healthy $30 million annual budget (140 yen/$1.00). Realizing the importance of research for enhancing its competitiveness in domestic and overseas construction markets, Ohbayashi has increased the staff and budget of the lab by 11% and 23% respectively over the past five years. Approximately 20% of the revenues for the lab are generated by outside consulting contracts.

As mentioned previously, the technologies developed in the labs are generating steady income streams through increased contracts awarded and licensing arrangements. Some of the proven and successfully licensed technologies developed within Ohbayashi's lab include:

Innovation	# Projects Used On	# Licensing Agreements
1. Base Isolation System (See Figs. 4, 5)	3	5
2. Foam Injection Shield Tunneling Method	34	15
3. Aqua Concrete (a non-segregating underwater concrete)	40	10

Table 1 - Innovation Data Sheet
(Courtesy of Ohbayashi Corporation)

The following are descriptions of just four of the more recent construction technologies enabling Japanese contractors to increase their contracts domestically and overseas.

INNOVATION #1 - DYNAMIC FLOOR SYSTEM:

The seismic or dynamic floor is a system which permits sliding of floors to protect computers and other sensitive office equipment during earthquakes. Developed by Ohbayashi, the system has now been installed in more than 50 buildings throughout Japan totalling nearly half a million square feet of office space! The most recently completed project to date has been the Sumitomo Bank, located in Kawasaki, which used the system for its 3rd, 4th, and 5th floor computers. Seven (7) new projects are scheduled for this year. (See Fig. 6)

The patented dynamic floor system required two years and approximately $300,000 to develop - a modest time and capital expenditure considering the success of the system since it was introduced. The dynamic floor system provides an attractive economic alternative for the protection of computer office equipment in comparison to the more costly base isolation system (another earthquake neutralizing system which requires the entire structure's foundation to be specially fitted with rubber pads and steel dampers). The dynamic floor system, on the other hand, can be installed for any particular floor desired and can even be retrofitted into existing buildings. In fact, 25% of the dynamic floors installed by Ohbayashi to date have been retrofitted.

SYSTEM MECHANICS:

Essentially, the system consists of a double floor, with a movable or dynamic floor built 18 inches above a fixed floor. The dynamic floor bears on vertical springs encased in 14 inch diameter steel cylinders. Two oil dampers located on either side of the cylinder absorb and neutralize most of the vertical seismic shock.

To counteract horizontal movements, each cylinder has a mechanism that allows it to slide. This consists of a teflon-coated steel shoe under the cylinder that can slide 8 inches in all directions on the 40 inch stainless steel plate attached to the fixed floor.

To prevent sliding when an earthquake is not occurring,

the steel plate is fastened by four horizontal springs which are in turn anchored to the fixed floor. Steel rods inside the cylinders support the dynamic floor and prevent the floor from responding with spring action to persons walking in the computer room and other loads. Under the impact of a vertical shock, the dynamic floor is released from these rods by a spring latch. Since its development, the system has undergone only minor design changes primarily in the spring latch mechanism. (See Figs. 7, 8)

PERFORMANCE RECORD:

Japan (like California) is a country prone to earthquakes. In the 5 months spent in Tokyo, the author experienced no fewer than 3 earthquakes - the last one causing cracks in the concrete walls of the dormitory rooms.

In 1976, an earthquake registering 6.4 on the Richter scale was recorded at the All Nipon Airways Computer Center located at Haneda Airport. Although the acceleration caused by the earthquake reached 300 gals (cm/sec^2) at the sixth floor's fixed floor, the dynamic floor 18 inches above reduced the acceleration to only 120 gals. No computer damage was reported at the sixth floor.

COST/MAINTENANCE:

The present cost (1987) for the system ranges from $50 to $60 per square foot. Even after adjusting for the sharp appreciation of the yen, the current cost is approximately 50% lower than when the system was first introduced in 1976. According to Mr. Okuda, chief engineer for the system, the dynamic floor is designed to last the life of the building. The only maintenance required is the resetting of the spring latches after an earthquake occurs.

INNOVATIONS #2 AND #3 - AUTO-CLAW AND AUTO-CLAMP:

These two robotic devices are used for steel beam and column erecting on construction sties. The auto-claw (beam erector) was recently developed this year and has been used on one project thus far (Kawasaki Steel Factory in Chiba Prefecture). Meanwhile, the auto-clamp (column erector) was developed in 1986 and has been used on 3 projects so far. Both construction robots have been developed to speed up erection time and to minimize the risks incurred by steel workers.

SYSTEM MECHANICS:

Auto-Claw - Two steel clamps extend from a steel encased unit containing a DC battery pack, electrical panel, and microprocessor unit, which is in turn suspended from a standard crane. The two clamps have a rated capacity of 2 tons each and can be adjusted to fit beam flanges from 8 inches to 12 inches. The clamps are automatically released by remote radio control once the beam is securely in place. Fail-safe electronic circuitry prevents the accidental release of the clamps during erection by keeping the circuit broken at such time. The steel beams require no special preparation when using this robot. (See Figs. 9, 10, 11)

Auto-Clamp - The essential purpose and mechanics are the same as the auto-claw except that the auto-clamp uses a special electro cylinder steel tube to secure and erect columns. Basically, a steel appendage plate with a hole in the center must be welded to one end of the column. The steel cylinder is electrically inserted and locked into the hole by remote control, whereupon the column can be erected. The appendage plates must be removed after the columns are erected. Like the auto-claw, the auto-clamp has a fail-safe system preventing the cylinder from retracting from the hole during erection. (See Fig. 12)

PERFORMANCE RECORD:

On the four projects using these robots, safety records indicated no accidents were incurred by steel workers. With the remote control securing and releasing feature, workers do not endanger their lives by having to climb the tops of columns or center spans of beams to release cables. While this feature undoubtedly reduces the time involved in the erection process, precise data has not yet been quantified.

MAINTENANCE:

In addition to periodic checks to ensure proper oil levels, electrical cables and hydraulic hoses, the only major servicing is the daily or weekly charging of the battery. If the robots are used 1-2 hours per day, weekly charging is required. However, if used continuously, the battery must be charged every day.

INNOVATION #4 - HORIZONTAL CONCRETE DISTRIBUTER:

The purposes of this construction robot are to reduce the manpower and improve the efficiency of concrete pours, as

the manpower and improve the efficiency of concrete pours, as well as minimizing the deterioration of reinforcing bar arrangement. Developed by Takenaka Komuten four years ago, the Horizontal Concrete Distributer (HCD) has been used on 17 projects throughout Japan.

SYSTEM MECHANICS:

The HCD is a hydraulically driven 3-boom telescopic arm that cantilevers from a steel column. The boom can extend 20 meters (66 feet) in all directions over a 1000 square meter (11,000 square feet) surface area.

A cockpit located at the end of the distributer houses the controls for an operator to manipulate the boom direction and flow of concrete. A new prototype model is remote controlled and prevents collision against existing columns by inputing their grid coordinates into the system. The weight of the robot is approximately four tons and can be raised up the column by jacks for the next concrete pour. On average, this relocation procedure takes only 1.5 hours. (See Fig. 13)

PERFORMANCE RECORD:

In all of the 17 projects using the HCD, the required manpower was reduced on average by 30%. The number of persons needed to spread and finish the concrete floors averaged 8 to 9 workers. Unlike the conventional concrete pump, the HCD eliminated the 4 or 5 workers needed to carry the pump and distribute the bulk volume of the concrete.

CONCLUSION:

The paucity of construction R&D spending by American firms is alarming in comparison to their Japanese counterparts. According to a 1986 MIT survey, of the 10 largest Japanese contractors which responded, 100% indicated they conduct R&D. In contrast, of the 11 largest U.S. contractors which responded, only 3 indicated they conduct R&D. A task-force for the Strategic Transportation Research study found that research on highway construction in 1982 was only 0.17 percent of our total $1 trillion investment in highways.

Further compounding these deficiencies are the short-time horizons characteristic of U.S. firms especially during periods of reduced profits. Of the 18 U.S. cement companies that had their own labs before the recession of the 70's, only 6 had labs afterwards. Meanwhile, Japanese construction

firms like Ohbayashi continue to increase the budget and staff of their labs despite declining profits over the past years.

More importantly, there is a definite correlation between such R&D expenditures and increasing market share. It is no coincidence that Japanese contractors working in the U.S. are now the fastest growing nationality group. Of the 39 Japanese contractors ranked among the Top 250 International Contractors, 22 reported new U.S. contracts two years ago. Their combined total has rocketed nearly 170% to $1.8 billion from 1984 to 1985. And last year, in fact, Japanese contractors did $2.5 billion in American contracts, a 39% increase from 1985. By using the advanced technologies developed in these labs, Japanese firms are bidding directly against American contractors and are winning. The same shield tunnel system mentioned previously in Table 1 was used by Ohbayashi in 1979 for winning the bid on a sewage tunnel in San Francisco, California. Remarkably, the bid price was $2.3 million lower than the second-lowest bid and $5 million below the engineer's estimate. Today, Ohbayashi is performing tunneling jobs in Los Angeles, Minneapolis and Washington, DC, and has captured a significant share of the U.S. tunneling market - a market traditionally held by U.S. giants such as Atkinson and Dillingham Construction. Even more alarming are the recent jobs won by Japanese firms for dams (Elk Creek Dam, Oregon) and deep diaphragm cut-off walls (Dept. of the Interior, Wyoming).

Given the increased competitiveness in today's construction industry and the technologies that are needed, it behooves U.S. construction firms to follow the lead set by Ohbayashi and other Japanese contractors. The policy of "retrenchment to protect our domestic market," as expressed by the president of one of the largest U.S. construction firms, is a prescription for decreasing market share, loss of jobs and perhaps bankruptcy as has been the case with the American steel and automotive industries. At stake is America's largest industry - one that performs $400 billion of work each year and employs 5.5 million people!

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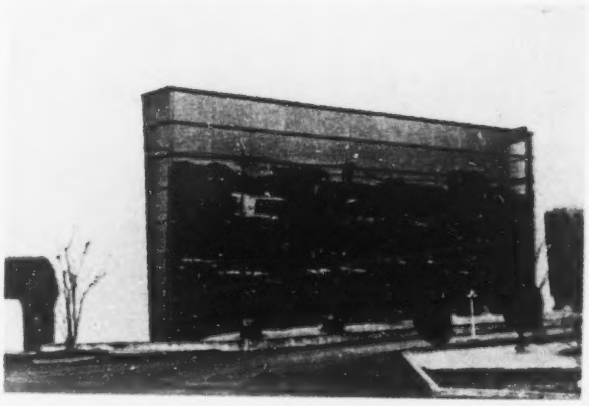

Fig. 1-Ohbayashi Corporation Technical R&D Lab

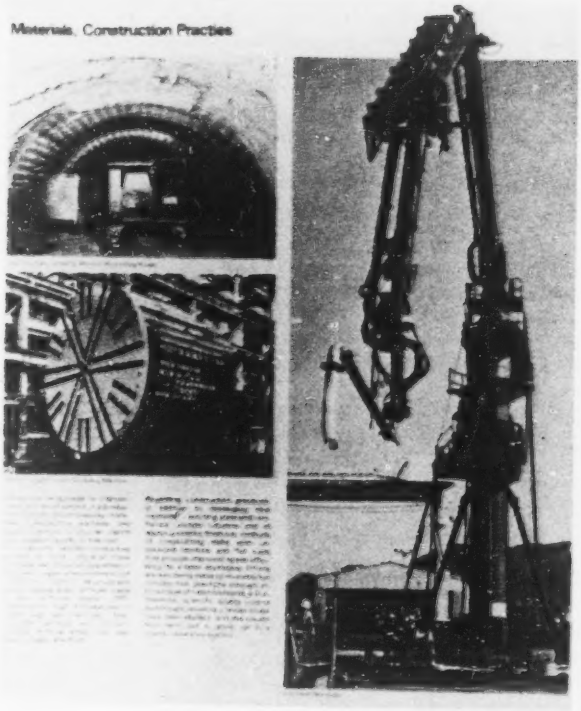

Fig. 2-New Construction Methods and Robotics (Courtesy of Ohbayashi Corporation)

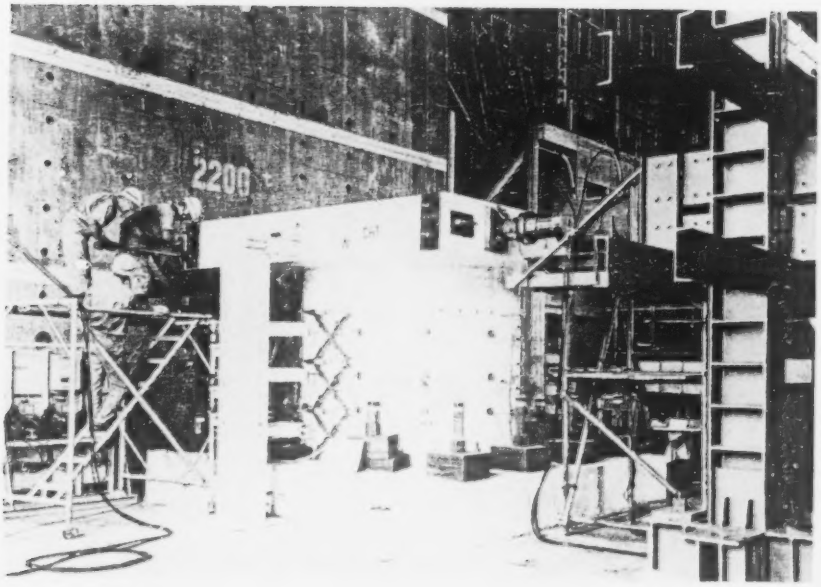

Fig. 3-Large Scale Structural Testing Facility equipped with a pair of 12m high reaction walls with loading capacity of 2,400 tons
(Courtesy of Ohbayashi Corp.)

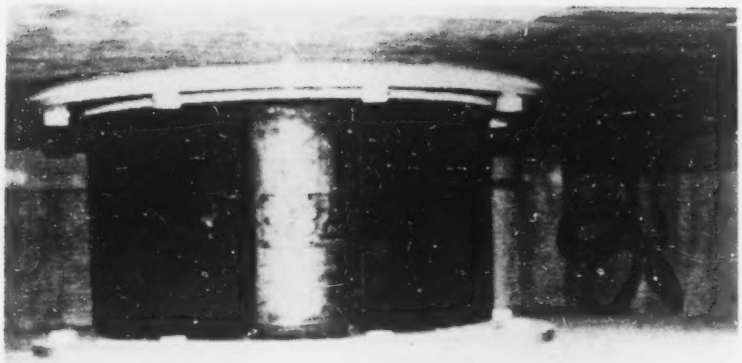

Fig. 4-Base Isolation System
-rubber bearing pad-
(Courtesy of Ohbayashi Corp.)

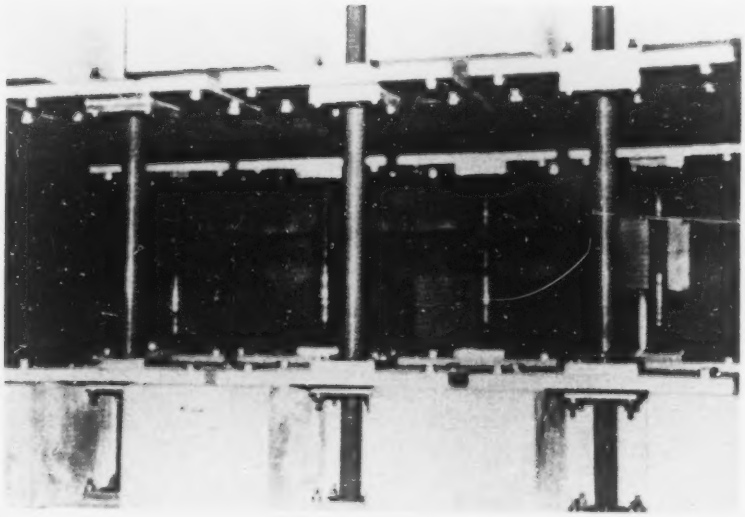

Fig. 5-Base Isolation System
-steel dampers-
(Courtesy of Ohbayashi Corp.)

Fig. 6-Author shown with Dynamic Floor System at Sumitomo Bank Project (Courtesy of Ohbayashi Corp.)

DIAGRAMS

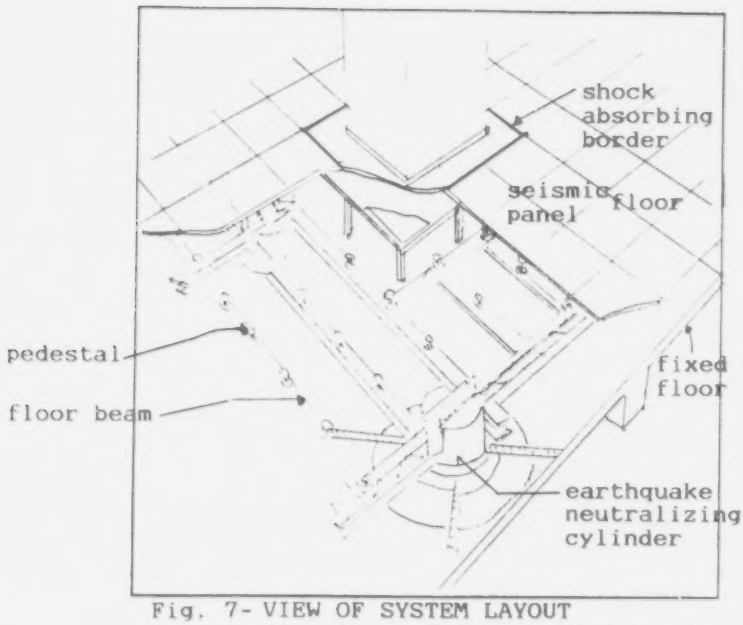

Fig. 7- VIEW OF SYSTEM LAYOUT
(Courtesy of Ohbayashi Corp.)

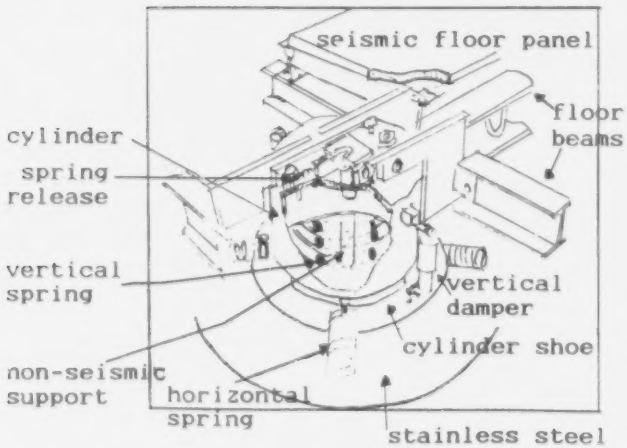

Fig. 8-DETAIL VIEW OF SPRINGS & DAMPERS
(Courtesy of Ohbayashi Corp.)

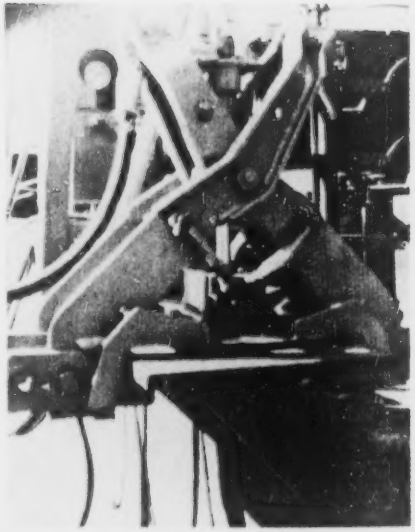

Fig. 9-Detail of Auto-Claw Clamp
12" maximum extension
2 ton rated capacity
(Courtesy of Ohbayashi Corp.)

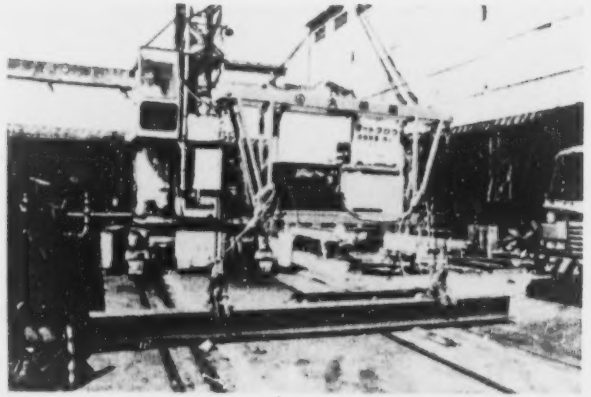

Fig. 10-Auto-Claw shown with steel frame
housing power source
(Courtesy of Ohbayashi Corp.)

Fig. 11-Auto-Claw hoisting steel beam with crane
(Courtesy of Ohbayashi Corp.)

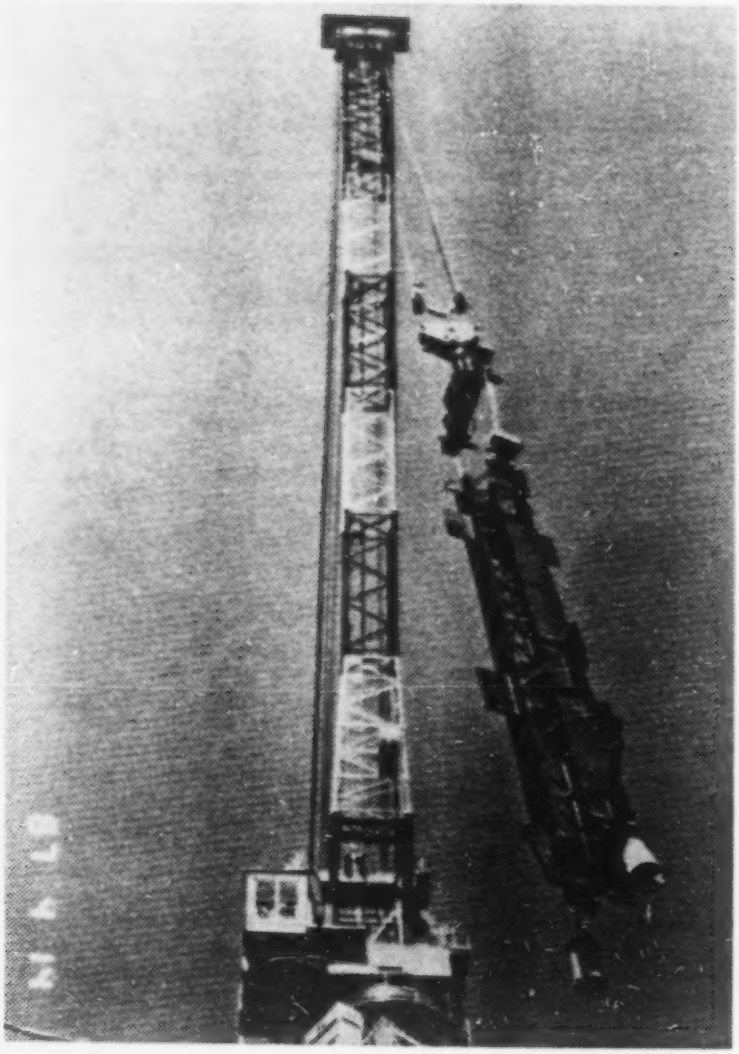

Fig. 12-Auto-Clamp shown erecting column
15 ton maximum capacity
(Courtesy of Ohbayashi Corp.)

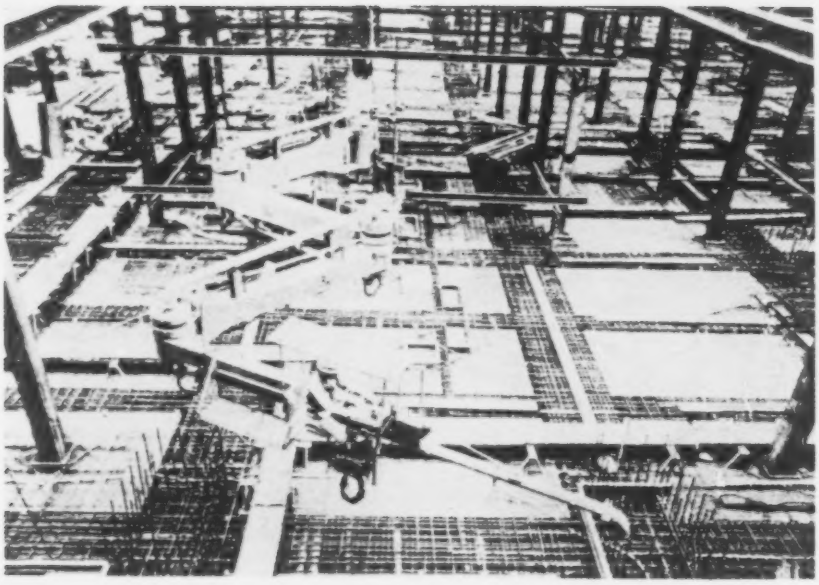

Fig. 13-Horizontal Concrete Distributer
66 ft. radius extension
area of coverage - 11,000 SF
(Courtesy of Takenaka Komuten)

INTERNATIONAL ENGINEERING &
CONSTRUCTION INDUSTRIES COUNCIL

1101 15th Street, N.W., Suite 1000, Washington, D.C. 20005
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Cordell W. Hull, Chairman
William W. Beddow, Secretary
Peggy A. Houlihan, Chairman
IECIC Action Committee

FOR IMMEDIATE RELEASE:

April 27, 1987

IECIC ANNOUNCES INDUSTRY COMPETITIVENESS PLAN

WASHINGTON, DC -- The International Engineering and Construction Industries Council (IECIC), a Washington-based organization representing some four million employees in the United States, has released a comprehensive plan calling for new legislation and policies to maintain and promote the viability of U.S. architectural, engineering, and construction (AEC) services overseas.

According to Cordell Hull, Chairman of IECIC: "Our government must recognize that the architectural/engineering/construction industry is of strategic importance to the United States as the vanguard of American exports of goods, products, machinery and diverse services. IECIC has developed a plan designed to increase the competitiveness of our industry both at home and overseas." According to IECIC data, ten years ago this industry captured 50 percent of the international construction market. Today that market share has dropped to about 25 percent.

Central to the "Design and Construction Industry Competitiveness Plan" is the need for competitive financing for AEC services.

- More -

IECIC calls for a significant expansion of the Trade and Development Program (TDP) which finances the planning of projects in developing countries which have significant potential for using U.S. goods and services in the design, construction, and operation of the project. Each dollar spent by TDP on feasibility studies from Fiscal Years 1980-1985 has produced about $178 of actual and potential exports.

The IECIC Competitiveness Plan also addresses U.S. access to the overseas AEC market, foreign competition in the United States, and the proposed inclusion of design and construction services in a new round of multilateral trade negotiations and in the U.S.-Canada Free Trade Agreement.

According to Hull, "The American design and construction industry, which has been facing an erosion of foreign markets over the past decade, is also losing out here in the U.S. Between 1980 and 1985, the value of engineering/construction contracts awarded to foreign companies in this country increased 2.5 times. No one expects this trend to reverse itself; in fact, most of us expect it to accelerate."

IECIC is an umbrella organization comprised of the National Constructors Association (NCA), the Associated General Contractors of America (AGC), the American Consulting Engineers Council (ACEC), and the American Institute of Architects (AIA). Together they employ nearly 4 million people in the U.S. The most recent data available shows that the a/e/c industries' foreign work is a major contribution to the U.S. economy, generating about $11 billion a year in economic activity in the United States. IECIC was formed in 1967 in order to address collectively issues which affect the export of U.S. architectural, engineering, and construction services. For further information, contact William W. Beddow, IECIC Secretary, at (202) 466-8880.

- END -

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April 1987

DESIGN AND CONSTRUCTION INDUSTRY COMPETITIVENESS PLAN

Dramatic action by the U. S. government is needed immediately to support the American design and construction industry in its efforts to compete in global markets. Ten years ago, this industry captured 50 percent of the international construction market. Today that market share has dropped to about 25 percent. Further, foreign design and construction firms are targeting the U. S. market and are making significant advances.

The International Engineering and Construction Industries Council (IECIC) has developed a plan to improve the competitiveness of the architectural/engineering/construction (A/E/C) industry in global markets. This plan provides specific recommendations (listed in priority order) for the Administration and Congress which should be seriously considered as trade legislation is developed this year.

EXPORT PROMOTION AND COMPETITIVE FINANCING

- The Trade and Development Program should be expanded and a new Competitive Finance Facility should be created to offer financing for overseas projects for which U. S. firms would be unable to compete effectively without U. S. government support. One hundred million dollars should be authorized to fund TDP over a two-year period, to be appropriated at $50 million in FY 88 and $50 million in FY 89.

- The Foreign Assistance Act of 1961 should be amended to ensure that trade becomes an integral part of U. S. foreign assistance policy and to ensure that AID funds are tied to exports of American equipment, materials and services. U. S. foreign assistance allocations should be balanced to provide both for basic human needs (BHN) and infrastructural projects to support BHN policies and other priority infrastructure.

- One billion dollars should be authorized for mixed credits to counter foreign subsidies in third country markets. The Trade and Development Enhancement Act of 1983 should be amended to provide wider access to AID's funds for mixed credits.

- American preferences should be expanded on overseas contracts funded by the U. S. government.

- U. S. agencies operating in foreign markets should contract out international work to the U. S. private sector.

- An interagency coordinating body should be established to monitor and integrate the activities of U. S. government agencies involved in A/E/C services in overseas markets with participation from the A/E/C industry.

- Relevant U. S. government agencies should be required to provide procurement information and to promote the participation of the U. S. A/E/C industry in projects funded by multilateral development banks.

- U. S. Foreign Commercial Service officers with specific responsibility for the promotion of the A/E/C industry should be placed in targeted countries which have a strong potential for the export of U. S. A/E/C services.

- A government role should continue for OPIC in providing coverage that is unavailable from private insurance companies.

FOREIGN COMPETITION IN THE U. S. MARKET

- Foreign A/E/C firms are generally free to compete in the U. S. market. The U. S. must insist on similar access to foreign markets for American design and construction firms. Selective sanctions should be applied against those countries which do not open their A/E/C markets to U. S. companies. Such sanctions should limit the access of A/E/C firms from these countries to the U. S. market.

JAPANESE MARKET/SECTION 301

- Congress and the Administration should continue their efforts to push for the opening of the Japanese A/E/C market, particularly in view of the free access accorded to Japanese contractors in the United States. The use of the unfair trade practices statute, Section 301, is one of the tools that the U. S. should consider using to support the American A/E/C industry. While this alone will not solve the problems of working in the Japanese market or the problems of Japanese competition in the U. S. market, serious consideration of a Sec. 301 action would be a significant step forward in recognizing the importance of the U. S. A/E/C industry to the American economy and U. S. jobs. Another option may be to impose sanctions against Japan if U. S. A/E/C firms do not receive a share of business roughly proportionate with the amount of A/E/C business that Japanese companies obtain in the U. S. market.

MULTILATERAL TRADE NEGOTIATIONS

- The A/E/C community has not yet reached a consensus on whether or not it would benefit from the new round of trade negotiations. However, since new trade rules for all service sectors are now being discussed, the A/E/C industry has developed the following negotiating objectives to provide guidance to the U. S. government:

- If A/E/C services are included in a new multilateral trade agreement, private sector technical advisors from the U. S. A/E/C industry should be involved in the negotiations. Active participation by the private sector will help ensure a successful agreement on A/E/C services.

- A separate sectoral code should be considered for architectural/engineering/construction services as opposed to inclusion in an umbrella agreement. The unique characteristics of the A/E/C industry require separate treatment.

- A/E/C services should be exempted from any agreement involving government procurement and labor: immigration regulations.

- The use of subsidies to win business in third country markets is escalating. A major priority of the U. S. in multilateral trade negotiations should be to limit the use of government export subsidies for international architectural/engineering/construction projects. Until such an agreement is reached, the U. S. should have competitive programs for meeting foreign government subsidies in export markets.

- Since the United States market is more open than other markets for design and construction services, trade negotiations should work toward the opening of the overseas markets to the level of accessibility of the United States market. Therefore, the multilateral trade negotiations should not be based on the premise that the United States should necessarily give up anything in this sector.

TRADE NEGOTIATIONS WITH CANADA

- Since the United States market is more open than the Canadian market for design and construction services, trade negotiations should work toward the opening of the Canadian market to the level of accessibility of the United States market. Therefore, the U.S-Canada trade negotiations should not be based on the premise that the United States should necessarily give up anything in this sector.

- The prohibitive Canadian tariff on architectural/engineering drawings effectively limits U. S. architects and engineers to the role of "design consultants" doing preliminary sketches and drawings. The U. S. no longer has a corresponding tariff. A high priority of the U. S. should be to have the Canadian tariff significantly reduced or eliminated.

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FACT SHEET

April 1987

IECIC Is:

	MEMBERS	INDUSTRY EMPLOYEES
National Constructors Association	20	130,000
American Consulting Engineers Council	4,700	130,000
Associated General Contractors of America	32,000	3,500,000
American Institute of Architects	12,000	52,000

IECIC represents directly almost 4 million architectural, engineering, and construction (AEC) employees in the United States with a total contribution to the U.S. GNP in 1982 of approximately $250 billion from services performed.

IECIC companies are a vital "opening wedge" in expanding American exports of goods, products, machinery and diverse services.

According to Price Waterhouse, in 1983:

- The U.S. AEC industry had export revenues of approximately $19.6 billion of which $4.8 billion represents direct U.S. revenues.
- An additional $6.1 billion of domestic revenues were generated as a result of AEC exports.
- For every $1 billion of direct revenues produced by AEC exports there is an additional $1.27 billion of indirect revenues from associated sales of goods and services, employment, etc.
- Total U.S. employment resulting from AEC exports was 261,000.
- Every $1 billion in total U.S. revenues generated by AEC exports results in approximately 24,000 jobs.
- Total U.S. wages resulting from AEC exports were $6.3 billion.
- Total federal corporate and personal income taxes resulting from AEC exports were $1.13 billion.
- AEC exports supported $1.4 billion in contracts to U.S. sub-contractors and the purchase of $1.9 billion in U.S. materials.